

BBC



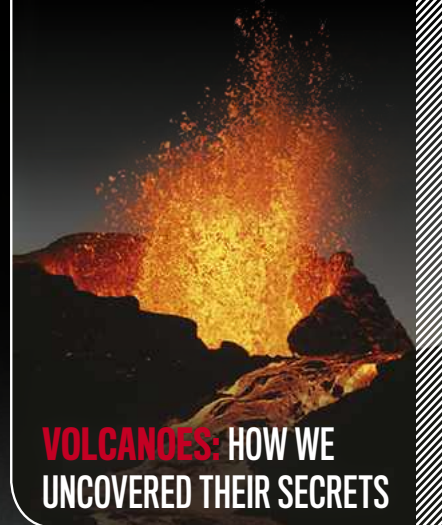
DRIVERLESS CARS
How will they cope with the UK's roads?

FOCUS

SCIENCE AND TECHNOLOGY

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ISSUE 277 / FEBRUARY 2015 / £4.25



VOLCANOES: HOW WE
UNCOVERED THEIR SECRETS

ONE WAY TO MARS

HOW WE'LL GET THERE.
HOW WE'LL SURVIVE.
WHO SHOULD GO.



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Q&A

- Why does it feel good to scratch?
- Does a brain with a high IQ burn more calories?
- Can germs survive on soap?

**TOMORROW'S
WORLD IN
PICTURES**

A sneak peek at
radical technology





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AWARDS 2014

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WELCOME



COULD YOU IMAGINE living in a place where you couldn't go outside without a protective suit? A place where there's little to do besides staying alive, and your only companions are work colleagues? Oh, and you'll never see your friends or family again.

That's what the would-be astronauts of Mars One will face if their mission to the Red Planet ever gets off planet Earth. The project is hugely ambitious, with much of the technology unproven. On p38, we ask some of the world's leading experts just what it would

take to make it to Mars, and establish a colony on the Red Planet.

Back on Earth, some people will be bracing themselves for floods this winter. A year ago, there were shocking scenes in the Somerset Levels and other parts of the UK. So on p60, *BBC Countryfile* presenter Tom Heap reveals what we've learned and how science can help.

I hope you don't encounter flooding this year, but you may see a driverless car because autonomous vehicles are now allowed on UK roads. On p54 we investigate how the technology works. Elsewhere we find out what tomorrow's world will look like (p48), the merits of adding lithium to water (p77) and how intrepid scientists studied volcanoes (p92). Enjoy the issue!

Graham

Graham Southorn, Editor

PS Don't miss our March issue, on sale 5 February 2015



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THIS MONTH WE...



...spoke to Todd B Kashdan, co-author of *The Power Of Negative Emotion*, on why embracing your anger is a good thing. Listen to Todd keep very calm on our podcast.

...went to the Digital Magazine Awards

and were delighted to pick up a highly commended gong in the science and nature category for the digital edition of *BBC Focus*.



...assaulted our eardrums trying out the audio capabilities of four different soundbars as part of this month's Ultimate Test. Turn to p89 to find out which model won.

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APPEARING IN THIS ISSUE...



Jo Carlowe

Jo writes for numerous titles, including *The Guardian*, *BBC Good Food* and *Cosmopolitan*. She asks whether adding lithium to water could be beneficial to our wellbeing on p77.



Kevin Fong

Kevin is an anaesthetist and author of *Extremes: Life, Death And The Limits Of The Human Body*. On p38, he explores the impact of a Mars mission on our bodies.



Tom Heap

Countryfile regular Tom is a broadcaster and journalist specialising in rural affairs, science and the environment. On p60 he uncovers 10 innovative ways to combat flooding.



Suzanne Bell

On behalf of NASA, Suzanne has carried out research studies on the psychological effects of space missions. She discusses the ideal traits of a Mars colonist on p38.



SUBSCRIBE AND SAVE

Turn to p34 to get five issues of *BBC Focus* for just **£5!**



SUBSCRIBER BONUS

On p34, **John Pickett** delves into the arguments for GM crops and asks if they could feed a growing population

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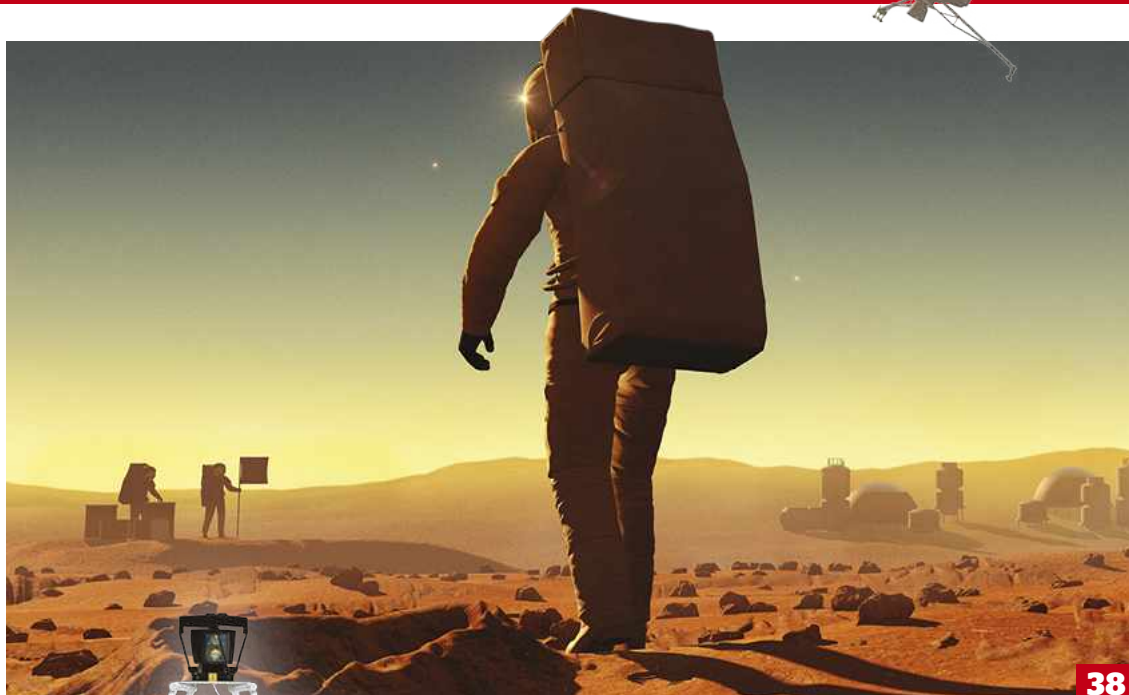
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Uncovering the story of our volcano knowledge



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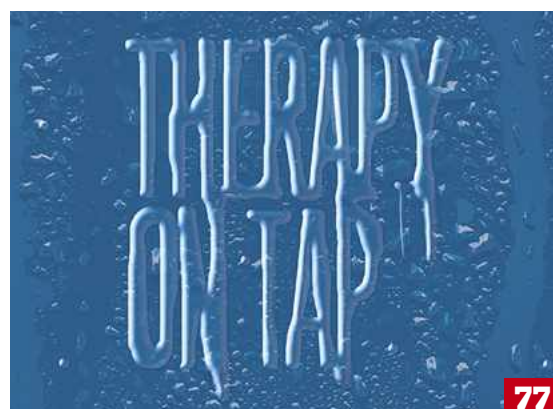
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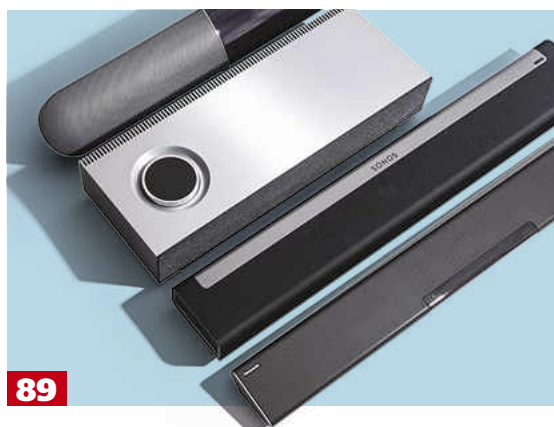
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Strain your brain with this month's quiz and crossword



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BBC Focus Magazine is distributed in the US as BBC Science World Magazine. BBC Science World Magazine (ISSN 0966-4270) is published 13 times a year by Immediate Media Company Bristol, 9th Floor, Tower House, Fairfax Street, Bristol BS1 3BN, UK. Distributed in the US by Circulation Specialists, Inc., 2 Corporate Drive, Suite 945, Shelton CT 06484-6238. Application to mail at Periodicals Postage pending at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to BBC Science World Magazine, P.O. Box 37495, Boone, IA 50037-0495.

Awe-inspiring images from the world of science

MegaPixel





The underwater river

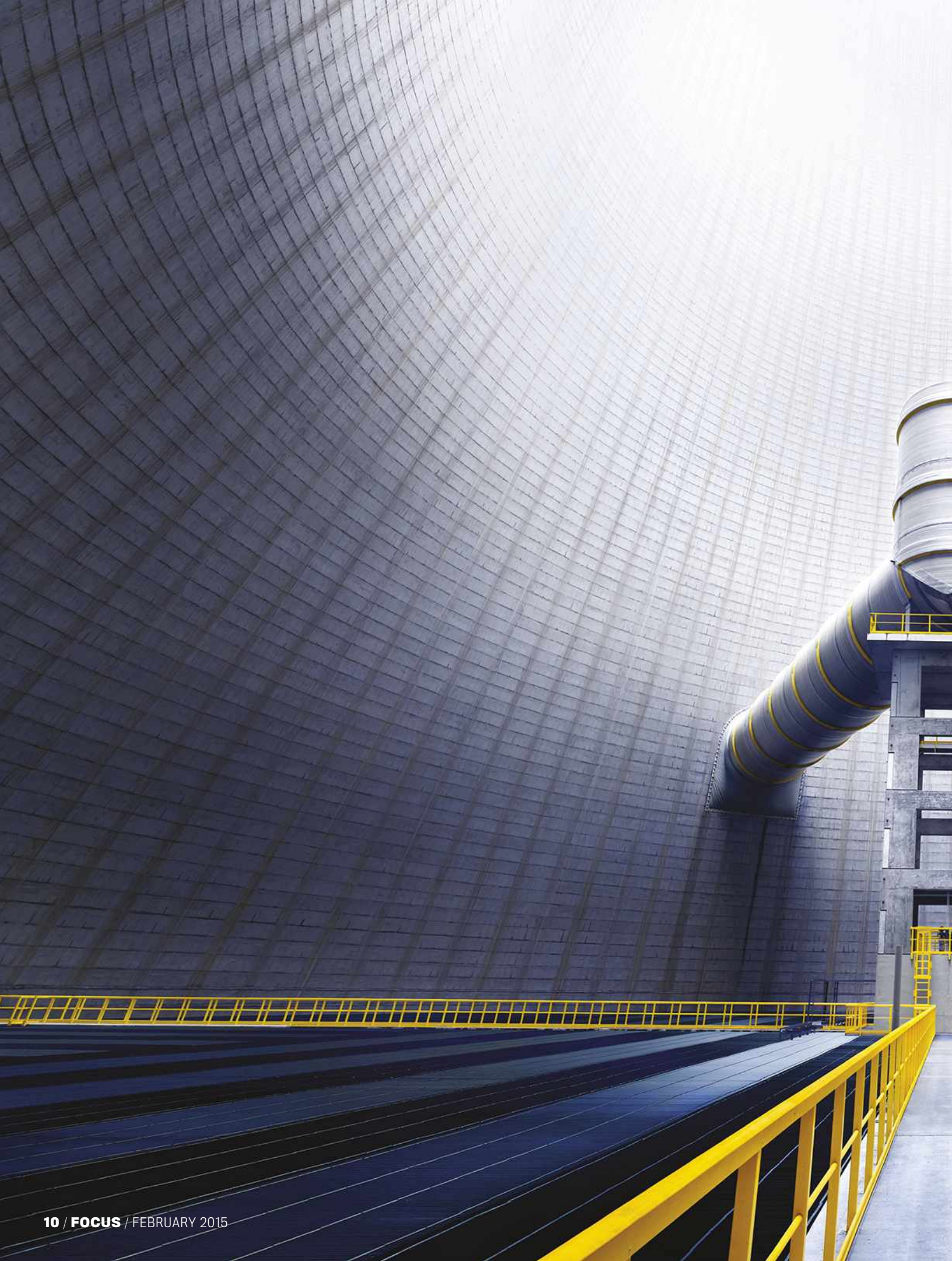
IF IT WASN'T for the bubbles coming from the diver's mouthpiece, this could be a moonlit river scene. But the bubbles give the game away: *everything* in this picture is underwater, and what appears to be a flowing river is actually a layer of cloudy gas.

This diver's paradise is a 'cenote' – a sinkhole formed by the collapse of limestone rock. Situated on Mexico's Yucatán Peninsula, the 60m-deep Cenote Angelita is flooded with a mixture of rainwater and seawater.

"The rainwater sits on top of the seawater because it's less dense," says Prof Mark Brenner, a geologist at the University of Florida. "In-between these layers there's also a trapped layer of hydrogen sulphide gas, formed by the decomposition of organic matter – that's the hazy 'river' you can see in the photo."

Floating branches and leaves in the foreground create the illusion of a riverbank, completing this surreal underwater tableau.

PHOTO: ANATOLY BELOSHCHIN





MegaPixel

Green steam

WELCOME TO THE cavernous innards of the Lünen coal-fired power plant's cooling tower. Situated near Dortmund, Germany, the tower stands 160m tall and 108m wide: it would take more than 48 million party balloons to fill it. It can burn 240 tonnes of coal per hour and generates 750 Megawatts of power. The coal is burned in fresh air at 1,300°C, producing 2,000 tonnes of steam to drive the turbines. The tower is then used to help condense the steam back down to water.

"Around 60,000m³ of cooling water per hour is forced into the tower by two huge pumps," says Stefan Paul, MD of Trianel, the energy company that operates the station. "Most of it drips down and is pumped back to the machine room; the remaining portion leaves the tower in the form of water vapour clouds."

The tower mixes and disperses cleaned flue gas from the plant, helping to improve efficiency. The plant is around 46 per cent efficient, making it one of the best performing of its type in Europe. Adding to its green credentials, an area of land has been set aside for the future addition of a carbon capture and storage plant.

PHOTO: LUCA ZANIER/ANZENBERGER



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Tons of tusks

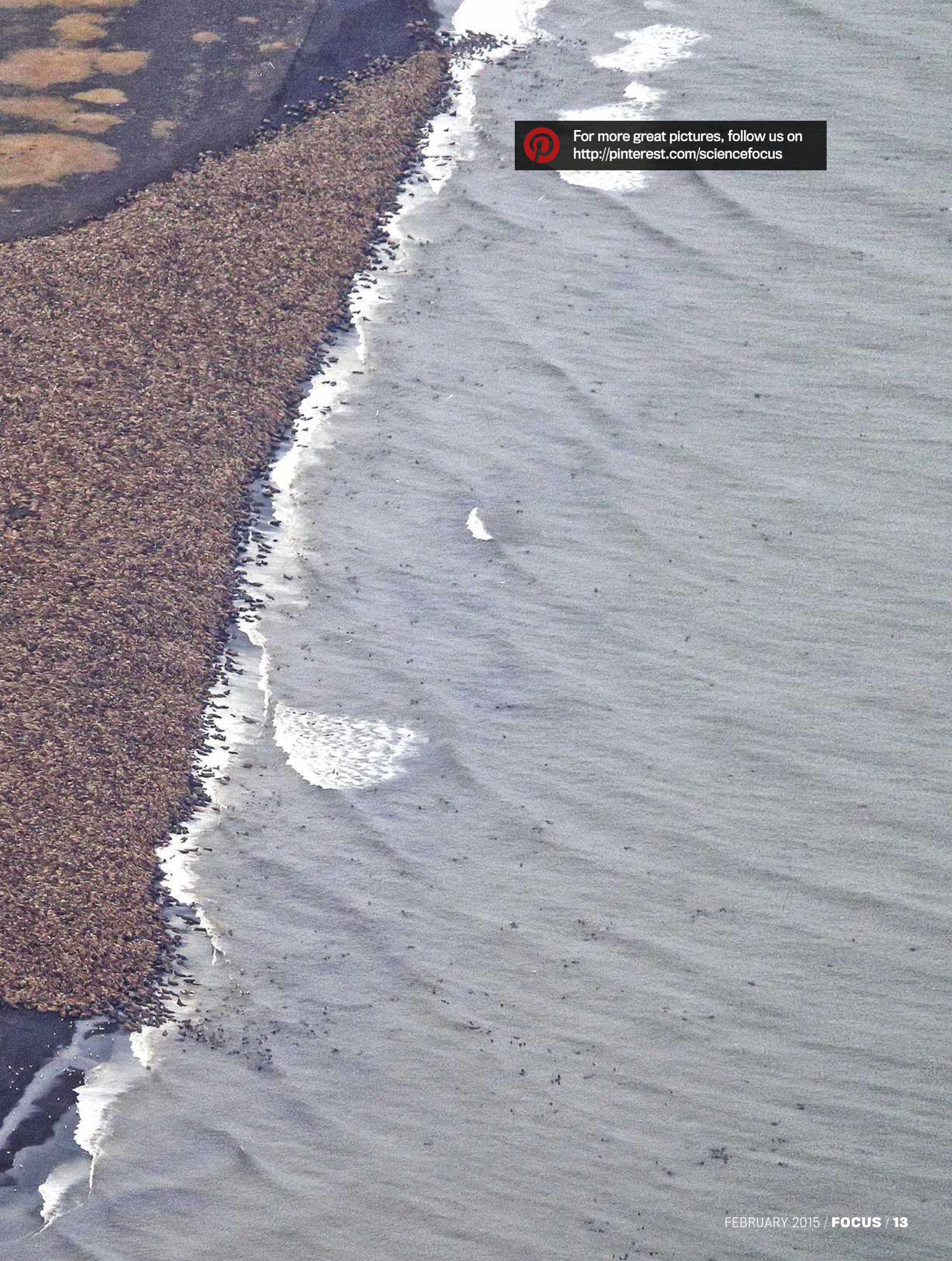
ON A REMOTE stretch of northwest Alaskan coast, 35,000 walrus haul themselves onto dry land to take a break from the chilly Arctic waters.

Because walrus aren't able to swim indefinitely, they need to frequently 'haul out' - leave the water to rest on their preferred terrain of sea ice. Unfortunately, due to the retreat of sea ice in summer 2014, they were forced to haul out on land instead. And what's especially unusual about this event is that most of the walrus are females and calves.

According to Prof Kit Kovac of the Norwegian Polar Institute, this haul-out was due to climate change. This view is echoed by Rod Downie, WWF UK's Polar Programme Manager. "This is one of the most visual examples of the dramatic impacts of climate change in the Arctic. Large-scale haul-outs such as this are dangerous for young calves, due to the risk of being trampled," he says.

We're likely to see this happen more often as climate change continues.

PHOTO: COREY ACCARDO/NOAA



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MESSAGE OF THE MONTH



Neanderthals have an undeserved reputation, says Jan Colebrook

Neanderthals: not brutish!

I MUST TAKE issue with your language evolution article [subscribers, December] about Neanderthals, which said: "Having the same genetic variant doesn't prove that they had language, and the Neanderthals' relative lack of cultural sophistication compared to humans living at the same time isn't consistent with having language."

This doesn't take into account current research and plays into the old stereotype of a brutish, ignorant Neanderthal, when recent discoveries are starting to show a different picture. Apart from the FOXP2 gene, fossil evidence shows that the Neanderthal brain had the same two speech centres as *H. sapiens*, Wernicke's and Broca's. They were both as large as our own, indicative of the ability to speak.

Earlier this year, researchers at the University of New England re-examined a 60,000-year-old Neanderthal hyoid bone – part of the mechanism by which people speak – using 3D x-ray imaging. They compared what they found with modern hyoid bones, and found that "in terms of mechanical behaviour, the Neanderthal hyoid was basically indistinguishable from our own, strongly suggesting that [it] was used in the same way". They concluded that the origins of speech and language are far older than was thought.

Even the degree of "lack of cultural sophistication" compared to *H. sapiens* is being called into question. Cave art, in the shape of handprints and an abstract engraving in the form of deeply impressed

cross-hatching has been found in Gorham's Cave, Gibraltar, and dated to at least 39,000 years ago – a time which predates the arrival of anatomically modern humans in Europe. Both support the hypothesis that the Neanderthals had a symbolic material culture.

Attitudes to the Neanderthals are changing, and this should, in my opinion, have been reflected in your article.

Jan Colebrook

Prof Mark Pagel replies: *Language is more than just saying words – many bird species can do that. It goes hand-in-hand with complex cognition – planning, imitating, negotiating, exchanging, drawing on the past and worrying about the future – and it is the outward indicators of this that are missing in the Neanderthals.*

Thus, by 40,000-50,000 years ago, modern humans living alongside Neanderthals in western Europe were leaving behind wondrous cave paintings, specialised and imaginative tools, bows and arrows, even musical instruments. By comparison, there is almost no evidence in Neanderthals for complex cumulative or symbolic thinking. Their tool kit was simple and remained largely unchanged for 300,000 years.

The same considerations apply to FOXP2, the so-called language gene. Very recent evidence shows that this gene is regulated differently in Neanderthals and humans, and so was expressed and used differently in the two species. Broca's and Wernicke's areas are also found in chimpanzees, and we know they don't have language. If the Neanderthals had language, one can only wonder why they did so little with it.



This 50,000-year-old Neanderthal skull was found in Gibraltar in 1848

+ Write in and win!

The winner of next issue's Message of the Month wins a Koubachi Plant Sensor 2 Indoor, worth £149. Its sensor measures light, moisture, temperature and more to check on your plants' health. It works over Wi-Fi with Apple or Android phones. koubachi.com



Bumpy landing



Philae: not an unqualified success, says Matthew Wilson

The Philae probe landing on a comet is wonderful but it's worrying that after the endless calculations and a 10-year plan to get there, Philae repeatedly bounced, forcing a second landing. The makers admitted that the thrusters failed and the harpoons didn't initially work. Just like the British Mars probe, Beagle 2, the mission could have been over before it'd begun! Still, the photos that have been sent back are amazing – it was a rocky start but worth the wait.

Matthew Wilson, Wolverhampton

However rigorous the simulations, I don't think they could have prepared Philae for all eventualities of a landing in space. Let's hope that Philae comes back to life as the comet gets closer to the Sun. – Ed

A vein hope

If finger vein recognition [December, p93] becomes widely used for secure banking, what will happen to customers like me who have a circulatory disorder?

I have Raynaud's Disease, which causes the blood vessels in my fingers to constrict and reduces the blood flow. Even with medication my fingers are constantly cold. I am sure there will be many others with similar problems.

Alan Padwick, Kingston Upon Hull

The banks need to think about backup systems. Perhaps people for whom vein recognition is impractical might be given iris recognition for security instead. – Ed

Game on

Am I the only one who sees a flaw in the test used by psychologists at the



Computer gaming builds gaming skills, argues Steve Varman – not, necessarily, sensorimotor skills in general

University of Toronto to compare the sensorimotor skills of computer gamers and non-gamers (December, p20)?

The test was a computer game which involved tracking an icon on a screen – a skill that gamers would have honed over hours of game play. From this, the psychologists deduced that gamers would be able to ride a bicycle better than a non-gamer. Following this triumph, perhaps next they could give knitters and non-knitters a crochet test, to determine who would make the best chefs?

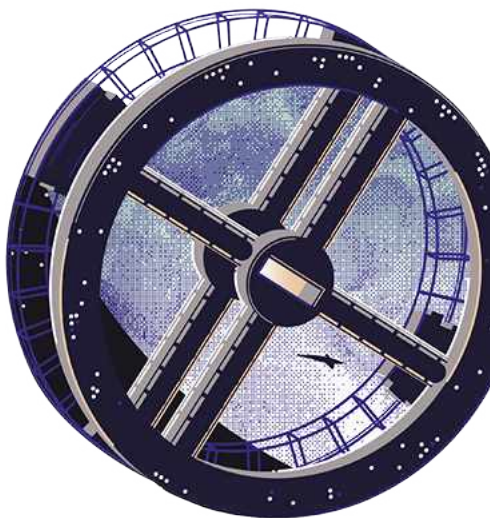
Steve Varman

The science of *Interstellar*

I read with great interest Helen Pilcher's 'Hollywood Science' article on 2001:

A Space Odyssey (December). It was interesting to read about the spinning space station to create artificial gravity, as this was exactly what they do in *Interstellar*. According to film consultant Kip Thorne, the one thing he wasn't sure about was the 'ice clouds'. One other minor error is that, being so close to a black hole, x-rays from the accretion disc around it would fry the craft and crew – that is, unless we developed a material to withstand them. Also, the light from the accretion disc would be different colours due to the Doppler effect.

I hope one day we will be able to manage a trip into 'interstellar' space, complete with spinning space stations.
Francine Lorrman, Peterborough



Spinning space stations? Bring it on, says Francine Lorrman

Solving mazes

I like Helen Pilcher's idea of the peanuts and crisps to keep track of your progress in a maze [October, p114]. But what about the birds and rodents who come along behind you and eat them?

C Henry Depew, Florida, USA

FOCUS

SCIENCE AND TECHNOLOGY

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Annual subscription rates (inc P&P):
UK/BFPO £55.25; Europe & Eire Airmail
£54.96; Rest of World Airmail £59.99.
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DISCOVERIES

News and views from the world of science

EDITED BY
JASON GOODYER



p20

AI: SHOULD WE BE WORRIED?

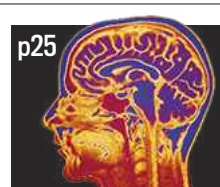
Artificial intelligence is developing in leaps and bounds. But is that a good thing?



p23

THE PILL THAT FIGHTS FLAB

Could the answer to all our dieting woes soon come in handy tablet form?



p25

THE BIRTH OF MEMORY

The exact brain location where your memories are made

THE BIG STORY

GRAPHENE PROMISES GREEN ENERGY REVOLUTION

The 'miracle material' just got even more miraculous, with the promise of more efficient hydrogen batteries

THERE'S A GOOD reason why graphene is often referred to as a miracle material. It's incredibly strong and light, and conducts heat and electricity extremely efficiently. It has the potential to be used in everything from bionic implants to computer chips. And now researchers have found another application to add to the ever-growing list: revolutionising hydrogen fuel cell technology. ➔

Protons (yellow) can pass through a thin sheet of graphene, a form of carbon

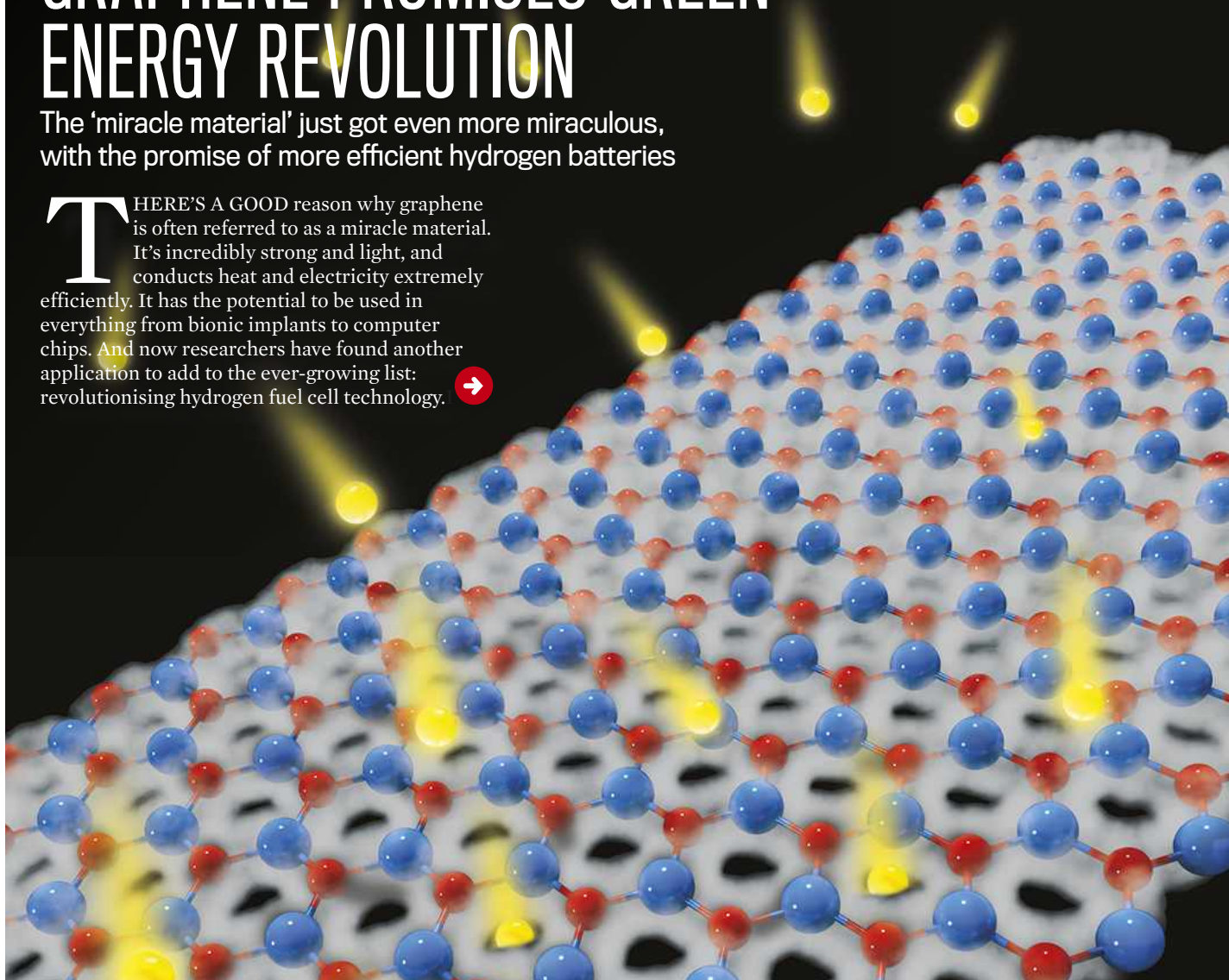


PHOTO: UNIVERSITY OF MANCHESTER

Graphene's properties could help revolutionise hydrogen fuel cells like this one



GOOD MONTH/ BAD MONTH

It's been good for: MEDITERRANEAN FOOD



A TEAM FROM Lund University, Sweden has found that a Mediterranean-style diet can lead to longer life expectancy and a reduced risk of heart disease. They found that those who ate diets high in vegetables, fruit, nuts and legumes, and low in meat and dairy, had longer telomeres on their chromosomes – a key indicator of age and health.

THE HARD OF HEARING

AT WEILL CORNELL Medical College, they've prevented noise-induced hearing loss in mice using the chemical nicotinamide riboside (NR). Mice given NR suffered less damage to nerves in their cochlea after being exposed to loud noises.

It's been bad for: ANTARCTIC GLACIERS

THE MELT RATE of glaciers in West Antarctica is increasing dramatically. A 21-year study by NASA has revealed that the average loss of ice from 1992 to 2013 was 83 gigatons a year, the equivalent of half of Mount Everest in weight. The average rate of loss increased by an average of 6.1 gigatons per year, but peaked at 16.3 a year between 2003 and 2009.

COMMUTERS



SQUEEZING ONTO a train filled with office drones or crawling along in rush hour traffic is unlikely to be anyone's idea of fun. But now researchers at the University of Waterloo in Canada have found that the more time people spend travelling to and from work, the less satisfied they are, as measured using the Canadian Index of Wellbeing.

➔ A single, one-atom-thick layer of graphene can form a barrier few things can penetrate. However, a team at the University of Manchester has found something that can: protons. Protons are hydrogen atoms stripped of their electrons, and they can pass through ultra-thin crystals of graphene surprisingly easily.

A barrier that's impermeable to everything except protons is required for hydrogen fuel cells to function. And the passage of protons was even easier at higher temperatures and when the films were covered with nanoparticles, such as platinum.

The use of graphene membranes could make fuel cells more efficient. And there was an even more exciting discovery. The group demonstrated that its one-atom-thick membranes were able to extract hydrogen

from a humid atmosphere. This harvesting technology could be combined with fuel cells to create a mobile electric generator, fuelled by hydrogen in the air.

"You put a gas containing hydrogen on one side, apply a small electric current, and collect pure hydrogen on the other side. This hydrogen can then be burned in a fuel cell," explained the paper's author Marcelo Lozada-Hidalgo.

"We worked with small membranes, and the flow of hydrogen is tiny so far. But this is the initial stage of discovery, and we want to make experts aware of the possibilities. To build up and test 'hydrogen harvesters' will require more effort."

To read our preview of the hydrogen-powered Toyota Mirai car, turn to p83



TIMELINE

A history of graphene

1947

Canadian theoretical physicist PR Wallace publishes a paper on the structure of graphite.

2003

Manchester University's Andre Geim (pictured) and Konstantin Novoselov create graphene for the first time, by peeling an ultra-thin layer from a block of graphite using sticky tape.



2010

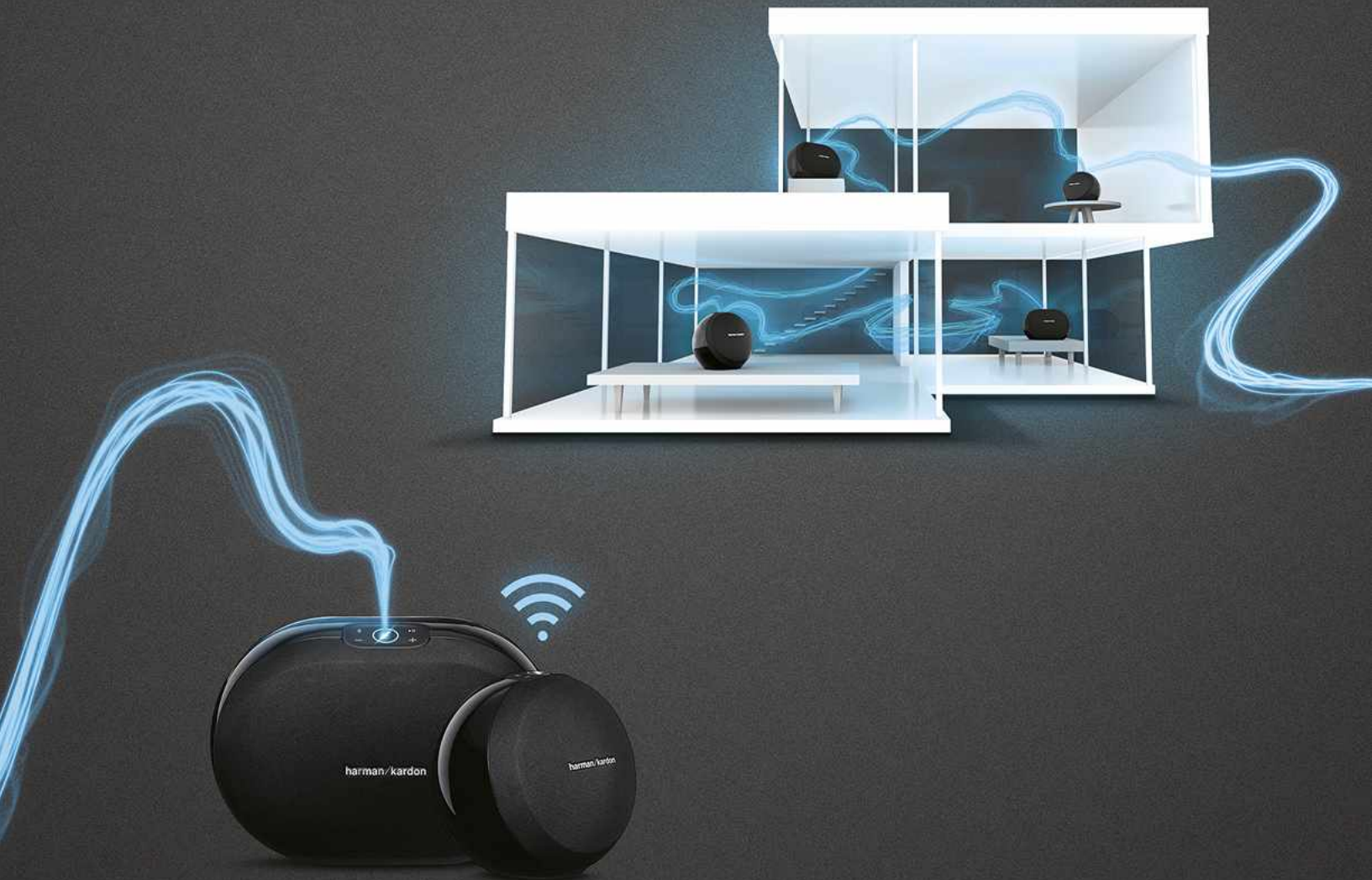
Geim and Novoselov are awarded the Nobel Prize in physics for the discovery of graphene, and their subsequent research into its properties.

2014

Samsung researchers develop a technique for 'growing' single-crystal graphene, bringing large-scale production of the miracle material closer to reality.

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DAVID SHUKMAN

The science that matters



We need to talk about artificial intelligence

AI increasingly permeates our everyday lives, but will any further advances spell danger?

THERE'S NOTHING LIKE the distinctive robotic voice of Stephen Hawking to stir up a heated debate about... robots. In an interview with my colleague Rory Cellan-Jones, Hawking warned that super-intelligent machines could end up wiping out us mere humans. That's the kind of statement that, in media terms, is like lighting the blue touchpaper.

Until recently, artificial intelligence seemed to belong in the realms of sci-fi. Back in the early 1990s, while filming in a US Air Force lab in Colorado, I caught a glimpse of just such a brave new world. The lab's

supercomputer, I was told, was cooled by the same plasma used in operating theatres: a liquid suitable for people bubbled past the circuit boards in what felt like a crossover between man and machine.

Since then, AI has slipped into our lives without most of us noticing. Order something from Amazon, search on Google or try (and usually fail) to make Siri understand you on your iPhone, and you're dealing with some form of artificial intelligence – albeit at a relatively simple level.

So what about machines that could actually *outsmart* humans: not merely on a chess

board, but in something as serious as decision-making or access to natural resources or even the survival of our species? A recent survey by a team at Oxford University found that most experts in the field pointed to the 2040s or 2050s before there's a realistic chance of producing a human-comparable machine. Other scientists say it's more like a century away.

Whoever is right, the debate about managing this new technology is already under way. Some researchers are investigating how any future machine would be 'scrutable' – transparent enough for rogue

behaviour to be fixed. Others are exploring how to engineer reliable controls so that a super-clever device can be guaranteed not to turn dangerous.

But there is a more optimistic perspective. Properly handled, AI might accelerate the search for new drugs to fight cancer, or help us find new ways to generate carbon-free electricity. Most new technologies face opposition of some kind and AI is no different. As ever, it's better not to leave the arguments until it's too late.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

THEY DID WHAT?!

Computer taught 'mind-reading' card trick

What did they do?

Researchers fed the method behind a 'mind-reading' card trick into an AI computer program, along with the

results of experiments into how humans respond to magic tricks. The AI learned the trick and created its own variations.

How does the trick work?

A deck of cards arranged in a known order is shuffled by an audience member, who is dealt six cards and then tells the program the colour (red or black) of each card. The



program then identifies the precise card picked by the audience member. See it at <http://youtu.be/xZiqkoaCaic>

Why did they do it?

"Using AI to create magic tricks is a great way to demonstrate the possibilities of computer intelligence," says co-author Prof Peter McOwan of Queen Mary University of London.

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1 MINUTE EXPERT

XNA



What's that?

XNA is a synthetic molecule created at MRC Laboratory of Molecular Biology in Cambridge.



Why make it?

Researchers have used XNA to create XNAzymes, the first ever enzymes made from artificial genetic material. They reckon they could offer insights into the origin of life and increase the range of planets that could potentially host living organisms.



How so?

All life on Earth relies on chemical reactions. Enzymes allow these reactions to occur at the necessary rate. XNAzymes are just as good at this as naturally occurring enzymes.



Do they have any other uses?

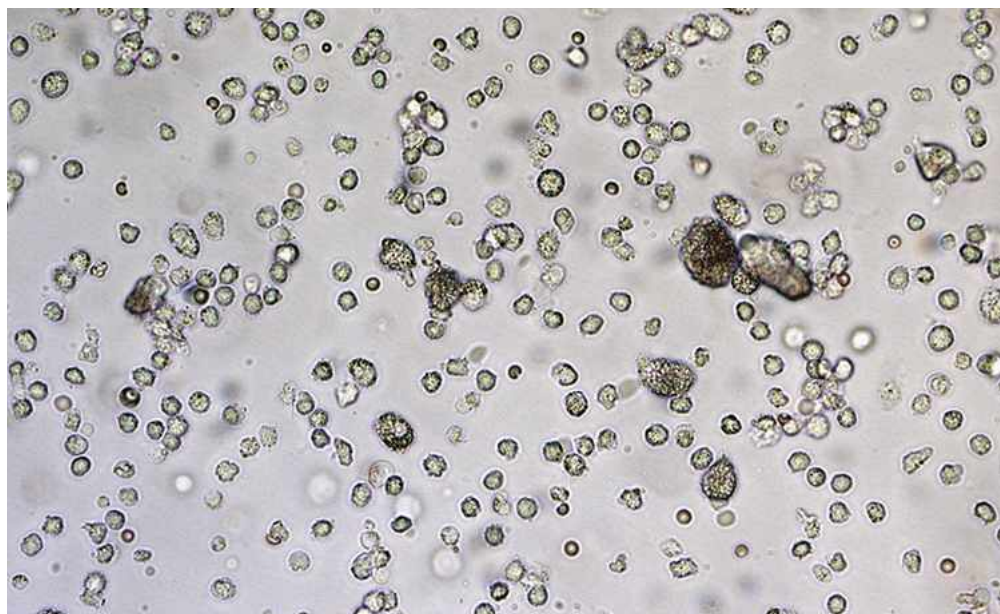
XNAzymes are more stable than natural enzymes. They may prove useful in developing new therapies for diseases that exploit the body's natural processes, such as cancer.



Enzymes are essential to life on Earth

HEALTH

Self-assembling 3D vaccines may help fight cancer



This microscope image shows immune system dendritic cells collected from the 3D scaffold

ONE DAY, TREATING cancer may be as simple as administering an injection. Researchers at Harvard University have created injectable vaccines that spontaneously assemble into 3D structures that could fight cancer as well as serious infectious diseases such as HIV.

The vaccines are made from tiny rod-like structures, known as mesoporous silica rods (MSRs). The pores within these little rods can be loaded with a variety of different drugs and the whole structure is then injected into patients with a needle. Once inside the body, the rods spontaneously form a 3D scaffold. This then attracts the body's dendritic cells, which direct the immune system to attack specific areas, such as cancerous cells. So far, the researchers have successfully tested the technology in mice.

"Right now we are focusing on developing a cancer vaccine. But in the future we may be able to manipulate the type of dendritic cells or other immune cells recruited to the 3D scaffold by using different kinds of drugs released from the rods," explains study co-author Aileen Li. "By tuning the surface properties and pore size of the MSRs, and therefore controlling the introduction and release of various proteins and drugs, we can manipulate the immune system to treat multiple diseases."

Since the vaccines can be produced quickly and easily, they might be used to fight rapidly emerging infectious diseases. Alternatively, they could be employed preventatively by building the body's immune resistance prior to infection.

WHO'S IN THE NEWS?



James Watson

Outspoken co-discoverer of the structure of DNA

• What has he done this time?

He has become the first living Nobel Prize recipient to sell their prize medal.

• Blimey! Why?

Watson says he became an outcast in the scientific community after suggesting that people of African descent were less intelligent than whites in 2007. He says that

this has greatly affected his income and he needed money.

• So, how much did it go for?

It raised \$4.7 million (£2.6 million) at Christie's Auction House in New York. The buyer of the medal, which Watson was given in 1962, was Russian oligarch and major shareholder in Arsenal football club Alisher Usmanov.

Usmanov gave it straight back to Watson, saying the sale was "unacceptable".

• What's Watson going to do with all that cash?

He said he intends to make donations to his alma maters Clare College, Cambridge and the University of Chicago, and would also like to buy a David Hockney painting.

TECHNOLOGY

NASA floats idea of high-altitude airship competition

AIRSHIPS ARE OFTEN dismissed as the playthings of eccentric millionaires, or flying billboards for famous tyre manufacturers. But NASA thinks they may have more to offer the world.

The space agency's Centennial Challenges programme is considering launching a multi-million dollar competition to build a record-breaking stratospheric airship. It has asked interested parties to come forward with their opinions and ideas.

Dubbed the '20-20-20 Airship Challenge', the aim of the proposed competition would be to create an airship that is capable of carrying a 20kg payload at an altitude of 20km for 20 hours. At present, no powered airship has been able to maintain this stratospheric altitude for longer than an eight hour period.

"The 20-kilometre mark is the sweet spot where the

airship would get as high as possible while still having enough air to propel against, because it needs propulsion to stay in the same spot. It's also a good altitude in terms

of average wind speed," says project leader Jason Rhodes.

NASA says it is currently trying to gauge the level of interest among the various communities that would be

interested in the project. The total prize purse may be up to a cool \$3 million, which could be split between multiple competition entrants.

Potential uses for the airship could include collecting data for studying weather and climate change, mounting a telescope on it to create high-resolution images of stars, and providing wireless internet to remote areas.

Artist's impression of a long-duration, high-altitude airship



HEALTH

Fat-busting pill on the horizon?

FAD DIETS AND gruelling exercise regimes may soon be a thing of the past for those looking to stay trim. Stem cell researchers say they have taken "the first step toward a pill that can replace the treadmill" when it comes to controlling obesity.

A team at Massachusetts General Hospital and Harvard University has created a system to find compounds that can turn white fat cells into brown fat cells using human stem cells.

White fat cells store energy as lipids and play a role in the development of obesity. Activated brown fat has been shown to burn white fat

and also reduces the insulin resistance associated with Type 2 diabetes.

So far, the researchers have identified two drugs that convert fat stem cells (which would normally produce white fat) into brown-like fat cells. One of these drugs is already available in the US, but is used for arthritis treatment. Its validity in promoting weight loss has not been clinically trialled. The researchers are now in discussion with pharmaceutical companies.

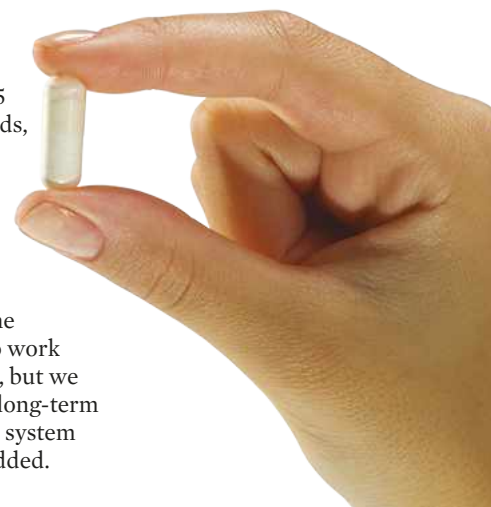
"We found these two compounds by screening a library of about 1,000

compounds," researcher Dr Chad Cowan says. "So we know that if we have access to the typical pharmaceutical company library of 1.5 to 2 million compounds, we will find others."

A collaborator in Germany has been testing the first two compounds on mice.

"We expect to have results fairly soon. The compounds appear to work the same way in mice, but we don't know what the long-term metabolic or immune system effects are," Cowan added.

Could a tablet keep us trim?





PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world



The sound of silence

IT'S 1AM. YOU desperately need to sleep, but your spouse is snoring, the traffic is roaring and next door they're pumping out the techno like it's 1992. If only there was a gadget that provided blissful, silent slumber!

Well, after one too many sleepless nights, three young engineers in the US have come up with Hush – smart earplugs that block out the noises you don't want to hear. Sound-eliminating foam acts as the first line of defence, while the in-ear speakers play soothing sounds such as ocean waves or crackling fire to drown out any residual noise. What's more, the earplugs connect via Bluetooth to your smartphone. This means that they can be programmed to let through certain alerts – your morning alarm, for example, or an important phone call you're expecting. Your neighbours' party will soon be nothing but a distant memory.

Patent pending

A step ahead

ACCORDING TO THE American Podiatric Medical Association, the average person walks 115,000 miles in their lifetime – that's more than four times around the equator. So it makes sense to learn how to do it properly. The Arki wristband from a South Korean start-up analyses your posture and provides feedback as you walk. Its accelerometer and gyroscope measure metrics such as your arm-swinging speed and rotation angle, vibrating if it detects that you're hunching your back or staring at the floor.

Patent pending

All sized up

ONLINE CLOTHES SHOPPING is fraught with danger, especially when skinny jeans turn out to be tighter than a pair of Lycra long johns. Three cheers, then, for the smart clothes invented by Israel's LikeAGlove. Simply slip on one of their elasticated garments – it could be a sock, a dress, a bra or a shirt – and it'll use its embedded sensors to measure your vital statistics. The data it collects is then transmitted to an app on your phone or tablet, where you'll be able to search for perfectly fitting clothes in your favourite retailers.

Patent pending

CHEMISTRY

Robot produces unnatural selection

THE ROBOT UPRISING may be one step closer. Researchers from the University of Glasgow have used a bot to develop a form of artificial evolution using simple chemicals.

"This is the first time that an evolvable chemical system has existed outside of biology," says researcher Lee Cronin. "Biological evolution has given rise to enormously complex forms of life, and our robot-driven form of evolution could have the potential to do something similar for chemical systems."

In natural selection, favourable genetic traits are passed on from one generation to the next while less favourable traits gradually die out. The team used a bespoke robot to create an iterative selection process that mimicked this effect.

First, the bot deposited four droplets of oil in water-filled Petri dishes. Each droplet was composed of a different mix of four chemicals. It then selected the droplet that best predetermined criteria. This droplet was then carried over into a second generation of droplets, and the process was begun again. After 20 repetitions the droplets became closer and closer to being ideal. The work may help scientists learn more about the origin of life as well as potentially producing chemical lifeforms, the team says.



KEY

1. Camera to monitor the droplets
2. Droplet injector forms the droplets
3. Data is sent to a laptop for analysis

Forget Skynet: the road to humanity's downfall starts with a modified 3D printer

NEUROSCIENCE

Where memories are born

WHETHER IT'S THE birth of your first child or your wedding day, all fond memories come from a specific region of the brain. And now a team at the University of Magdeburg, Germany, has successfully determined the precise location where memories are generated.

It was known that memories are stored primarily in the cerebral cortex, and that the control centre that generates and retrieves them is located in the brain's interior. The team was able to pinpoint this

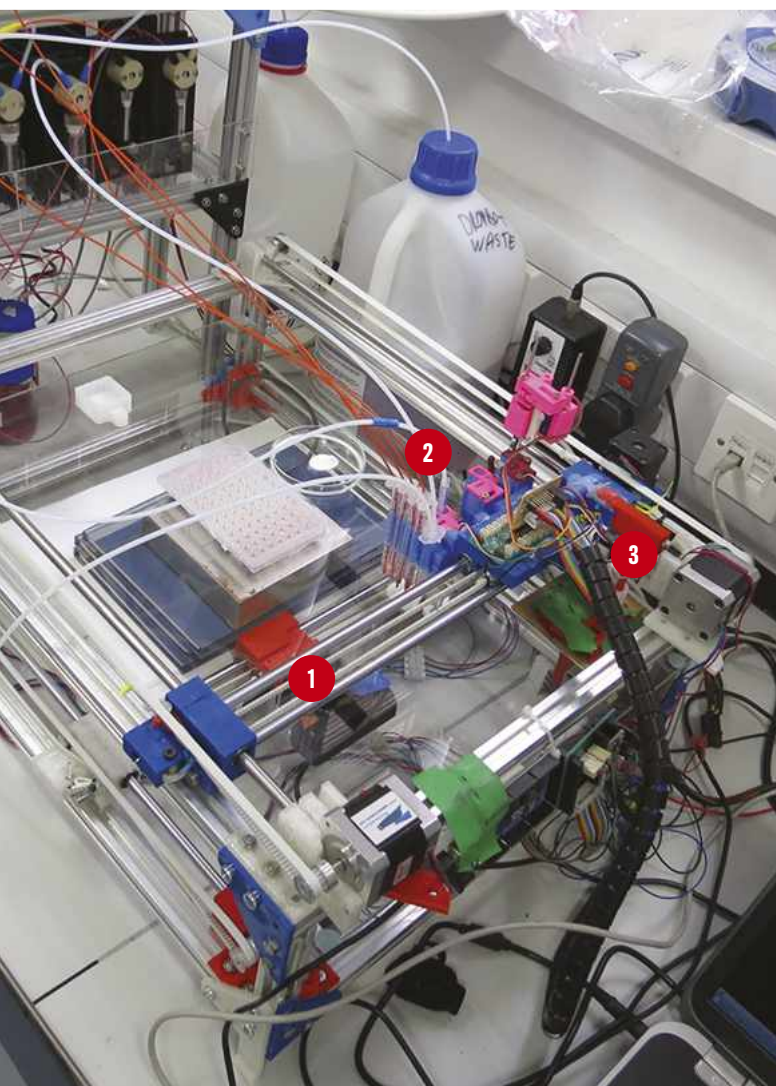
precise area in volunteers' brains during a simple memory test using a particularly accurate type of imaging technology known as 'seven Tesla ultra-high field magnetic resonance imaging'.

"We have been able to locate the generation of human memories to certain neuronal layers within the hippocampus and the entorhinal cortex," explains Professor Emrah Düzel. "We were able to determine which neuronal layer was active. This revealed if information was directed into the hippocampus, or



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New websites, blogs and podcasts



An fMRI scan of a human brain. A newer, higher-resolution form of MRI enabled the Magdeburg team to make their discovery



whether it travelled from the hippocampus into the cerebral cortex. Previously used MRI techniques were not precise enough to capture this directional information. Hence, this is the first time we have been able to show exactly where in the brain the doorway to memory is located."

It is hoped that the research will lead to new insights into the understanding of memory impairments, such as those seen in Alzheimer's disease.



CERN OPEN DATA

opendata.cern.ch

Fancy seeing how you'd fare as a particle physicist? This new offering from CERN could keep you busy for days on end analysing real data. It's not for the faint-hearted, and you'll need to do some downloading to get started, but if you put in the time you'll be rewarded with actual data taken at the LHC in 2010.



ANGLERFISH: APPROACH TO DEEP-SEA FISHING

<http://youtu.be/VqPMP9X-89o>

This is thought to be the first footage of the strange and elusive creature known as the 'black seadevil' (actually a type of anglerfish) in its natural habitat, 600m

below the surface of the sea. Watch the video, and you'll understand how the seadevil got its name.



DARWIN MANUSCRIPTS PROJECT

amnh.org/our-research/darwin-manuscripts-project

In this digitised collection of Charles Darwin's manuscripts, see with your own eyes the first time he used the term "natural selection". Don't miss the pages of an early *Origin Of Species* draft that only survived because they'd been used by his children for drawing on.



SEEING THE INVISIBLE

<http://youtu.be/ePnbkNVdPio>

Welcome to a world of things we can't usually see, starting in 1674 with Antonie van Leeuwenhoek and the drop of lake water he looked at under a microscope, revealing a hidden world of microorganisms nobody even knew existed. Watch his story unfold in paper animations, with useful resources for teachers just a click away.



KELLY OAKES is science editor at BuzzFeed. She tweets from @kaoakes

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10 Drying human tissue



There's something fishy going on here

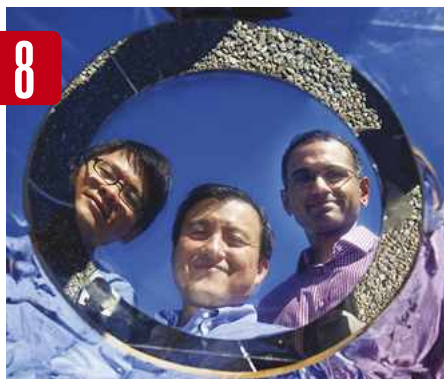
TECHNIQUES FOR MAKING salted cod may be used to preserve human tissue samples. Currently, tissue is preserved in either formalin at -90°C or liquid nitrogen at -193°C , but this method is very expensive. So a team at the Norwegian University of Science

and Technology is pioneering a method that involves drying samples with the kind of heat pump commonly used for making salted cod. The method requires much lower temperatures and has so far proved successful on samples from human lungs, heart and liver.

9 3D ultrasound shape can be 'felt'

RESEARCHERS AT THE University of Bristol have come up with a 'haptic' system that can create touchable shapes using ultrasound. By focusing complex patterns of ultrasound onto a user's hand, the device produces a 3D shape that can be felt in mid-air. The technology could enable surgeons to explore a CT scan by touch, enabling them to feel a disease such as a tumour, say the scientists.

Haptic technology could make life easier for surgeons



8 Mirrors cool buildings

AS WELL AS making sure your haircut is looking tiptop, it seems mirrors have another use: keeping buildings cool in summer. Dubbed photonic radioactive cooling, the technology off-loads infrared heat from within a building as well as reflecting sunlight that would otherwise warm it up. It uses ultra-thin layers of silicon dioxide and hafnium oxide and could reduce the need for air conditioning.

7 Malaria drug

A TEAM AT St Jude Children's Research Hospital in Tennessee has made a breakthrough in treating malaria. They have developed a drug that encourages the immune system to destroy infected red blood cells, while leaving healthy ones unharmed. The therapy may help to slow down the development of drug-resistant strains of the disease.



Malaria kills up to a million people worldwide each year

6 Using sewage to boost bioenergy crop growth

DESPITE BEING RICH in beneficial nutrients, wastewater cannot be used on food crops due to health concerns. Now, a team from Madrid has found the use of sewage can boost the oil seed production of Cynara, a type of thistle being developed as a bioenergy crop, by up to 68 per cent. The technique could be used with wastewater management systems to help produce biofuels.




Cynara thistles are native to the Mediterranean region

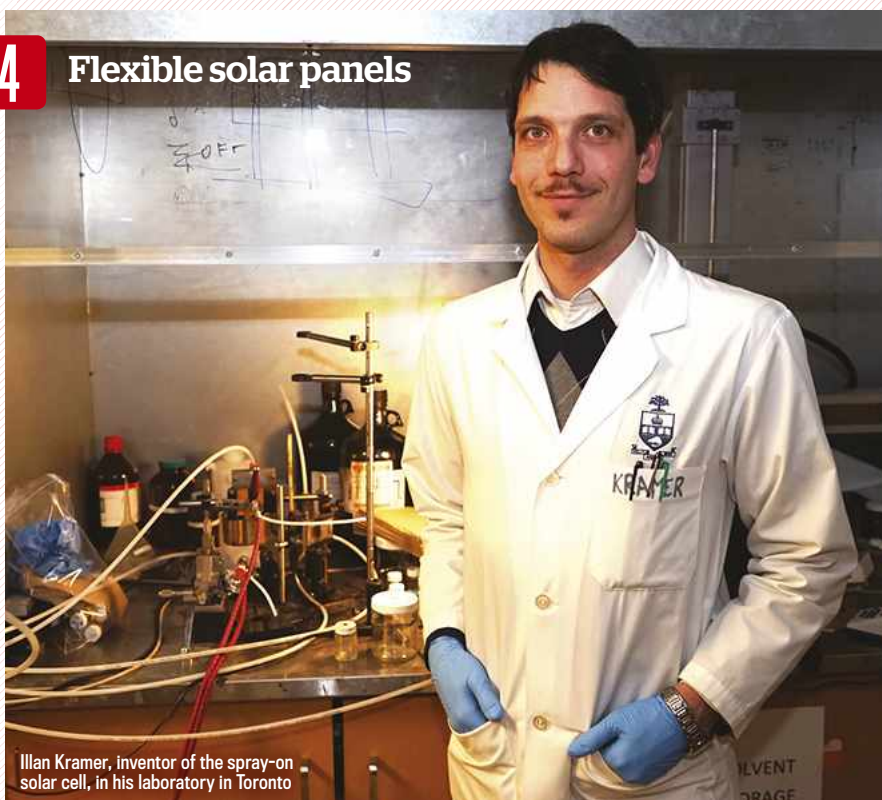
5 Artificial cow's milk

A TEAM OF bioengineers based in San Francisco has produced the world's first artificial cow's milk. **The product could be a more environmentally friendly alternative to regular milk**, the team says. Dubbed Muufri, the milk is made by extracting DNA from dairy cows and inserting it into yeast cells. The resulting cocktail of six proteins and eight fatty acids is then combined with other minerals such as calcium.

3 Synaesthesia could be key to therapy

 EVER FANCIED 'seeing' letters as colours? University of Sussex researchers found that subjects were able to do just that after nine weeks' training. They wanted to know whether the hallmarks of the neurological condition synaesthesia could be 'learnt'. **The techniques may lead to therapies for conditions such as ADHD or dementia.**

4 Flexible solar panels



Illan Kramer, inventor of the spray-on solar cell, in his laboratory in Toronto

SPRAY-ON SOLAR cells developed at the University of Toronto **could soon turn almost any surface into a power source**. Researchers incorporated materials known as colloidal quantum dots

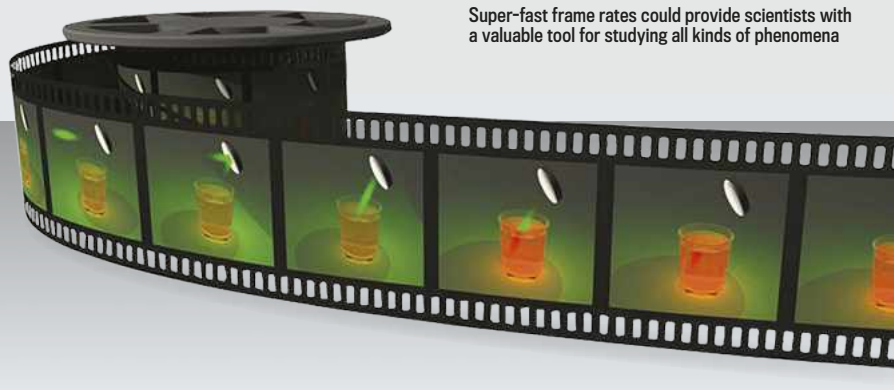
(CQDs) into a spraying system capable of depositing layers a single atom thick. The resulting solar cells proved just as efficient when tested as their more traditional counterparts.

2 Fastest ever camera

BIOMEDICAL ENGINEERS AT Washington University have produced a camera that can record 100 billion frames per second. Typical film cameras record just 24 frames per second. The camera uses a technique

known as compressed ultrafast photography and is so fast it can show the motion of light pulses. **The technology could help to improve our understanding of fast biological, chemical and cosmological processes.**

Super-fast frame rates could provide scientists with a valuable tool for studying all kinds of phenomena



1 A plastic that conducts heat

PLASTICS ARE HIGHLY versatile materials but they have always had one drawback: they don't conduct heat. Now, a team at the University of Michigan has created **a plastic that disperses heat 10 times more effectively than others**. The new material could be used in electronics or any other situation that requires prompt heat dissipation.



The new polymer does not restrict the flow of heat

PALAEOLOGY

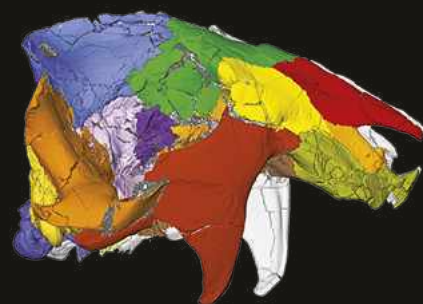
Mesozoic mammal reconstructed



The head of *Vintana sertichi*, with the skull's location highlighted, has large eyes for keen vision



Side view of the *Vintana sertichi* cranium - the large scimitar-shaped flanges had chewing muscles attached



Digital rendering of the animal's skull, with the individual bones highlighted in different colours

MEET *VINTANA SERTICHI*, a badger-sized mammal that lived alongside dinosaurs in what is now Madagascar. The animal lived between 72 and 66 million years ago, during the Mesozoic Era, and this detailed reconstruction was put together from CT (Computed Tomography) scans after a fossil was removed from a block of sediment in 2010. *V. sertichi* is a member of a group of extinct

mammals, the gondwanatherians, which are named after Gondwana, the ancient supercontinent on which they roamed.

The skull is 125mm long and the creature would have weighed 9kg, making it the largest primitive mammal of its era on Gondwana. At the time it lived, most mammals were the size of shrews or mice. Previously discovered fossils of gondwanatherians consisted only of isolated teeth and a few other

fragments, whereas the new specimen is almost complete. Analysis of the fossil has revealed that *V. sertichi* was a herbivorous animal that was agile, with keen senses of smell, vision and hearing.

"*Vintana* reshapes some major branches of the 'family tree' of early mammals, grouping gondwanatherians with others that have been very difficult to place in the past," says palaeontologist Dr David Krause of Stony Brook University.

SPACE SCIENCE

Origins of water

HOW DID TWO-THIRDS of Earth's surface come to be covered in water? One hypothesis is that Earth was so hot when it formed 4.6 billion years ago that any water would have boiled off. It was thought that the water was brought by comet and asteroid collisions once it had cooled down.

ESA's Rosetta craft has now discovered that water vapour streaming off Comet 67P is different to Earth's water. It contains almost three times as much deuterium – a form of hydrogen with an extra neutron that is also known as 'heavy hydrogen'. As the ratio between heavy and light water is largely constant, water from Earth is unlikely to have come from impacts from comets like 67P.

Researchers now say that asteroids are the prime candidates for having seeded the Earth's oceans throughout history. These rocky objects formed closer to the Sun than comets.

"We knew that Rosetta's in situ analysis of this comet was always going to throw up surprises for the bigger picture of Solar System science, and this outstanding observation certainly adds fuel to the debate about the origin of Earth's water," explains ESA Rosetta project scientist Matt Taylor.

"As Rosetta continues to follow the comet on its orbit around the Sun throughout next year, we'll be keeping a close watch on how it evolves and behaves, which will give us unique insight into the mysterious world of comets and their contribution to our understanding of the evolution of the Solar System," he adds.



Water vapour streaming off Comet 67P (pictured) has a different composition to water found on Earth



INSIDE SCIENCE

ROBERT MATTHEWS

Who's better at predicting events: experts or a pub crowd?

FOR ANYONE LIVING in the small Pennsylvanian town of Punxsutawney, 2 February is Groundhog Day. Each year, the townsfolk are joined by thousands more to witness a century-old ritual of prognostication performed by a groundhog. According to tradition, if the rodent – known as Punxsutawney Phil – sees his shadow and returns to his hole, spring is still six weeks away.

Groundhog Day was made famous by the eponymous 1993 movie, and it supposedly has its origins in an ancient Gaelic festival called Imbolc. Apparently, bright weather on that day pointed to continued wintry conditions.

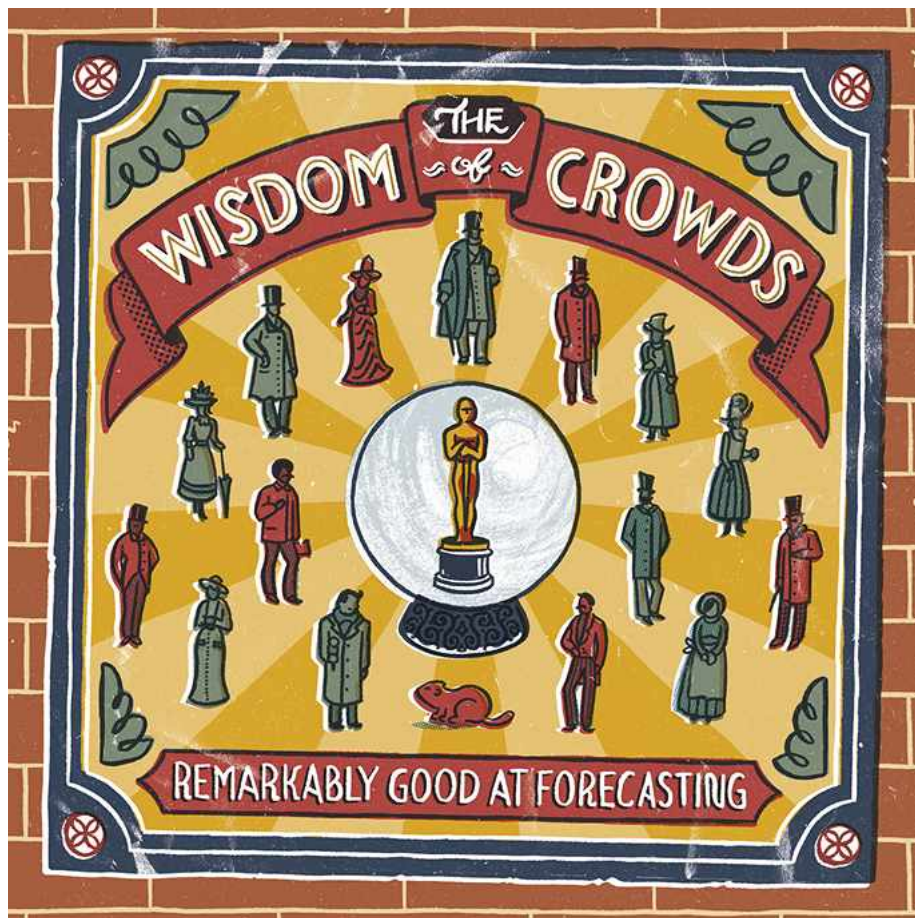
The reliability of Phil's strike rate is a bigger mystery. The most oft-quoted figure is around 35 per cent. Frankly, I'd be surprised if it were that low; something closer to 50 per cent, like a coin-toss, seems more plausible. As it stands, Phil's forecasts could be taken to be 65 per cent reliable – as long as you turn the traditional interpretation of his behaviour on its head.

In the absence of decent evidence, you'd be better advised getting your forecast from a bunch of people in the local pub. No really, you would. At least that way you stand a chance of tapping into the amazing phenomenon of the 'wisdom of crowds'. First identified around a century ago by a Victorian statistician, it is capable of emerging from groups of people whose individual insights have been pooled and then averaged.

You'd think the average of a lot of rubbish guesses would also be rubbish. Yet if you can persuade people to take the task seriously – by offering prizes, perhaps – and deter jokers by setting an entrance fee, it's surprising how reliable the average guess can be.

Over the years, so-called 'prediction markets' have proved excellent at forecasting everything from election outcomes to the success of new products. Want to know what films and actors are going to win Oscars in a few weeks' time? Then check out the HSX prediction market, which has been forecasting them with uncanny accuracy for years.

The wisdom of crowds may seem like nothing more mysterious than an opinion poll, but researchers have pointed out something weird about it. It seems to work even if the crowd is very small – say a few dozen people – and neither random nor very representative.



“While the crowd should include people with genuine insight, it's vital to mix in some mavericks as well”

Maybe the claims made for the wisdom of crowds are based only on examples where it happens to work, while the failures are quietly forgotten. But researchers are now uncovering the theory behind the phenomenon, along with handy tips for getting reliable forecasts.

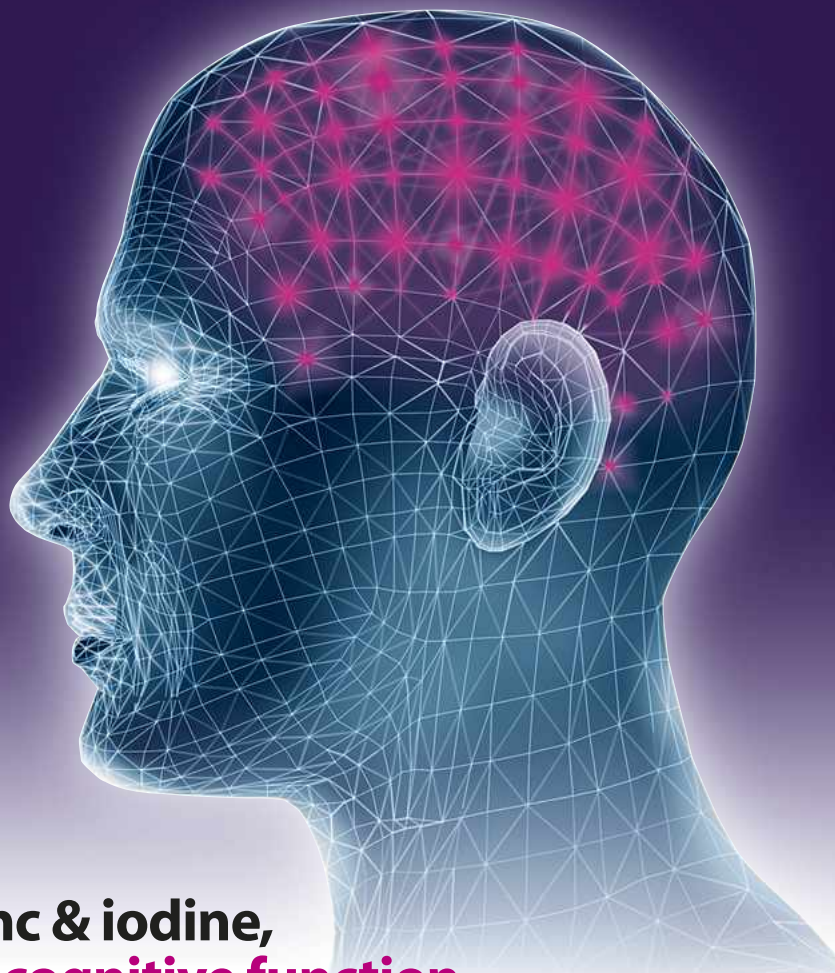
While the crowd should include people with genuine insight, it's vital to mix in some mavericks as well. That's because experts tend to think in similar ways and draw on similar evidence. A lack of diversity can prove catastrophic in trying to forecast events, like the global credit crunch which many expert economists failed to foresee. In fact, diversity is so important for reliable forecasting that it's actually worth swapping a few experts for less brilliant radicals, to cover off the 'unthinkable'.

There's another lesson lurking in the emerging theory behind the wisdom of crowds, though: beware of forecasts made by one individual, no matter how supposedly 'expert'. Many of us have a natural aversion

to 'gurus' and their touchy-feely prognostications, but it's nice to know that our scepticism has now been confirmed by some cold, hard mathematics. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

Feed your mind



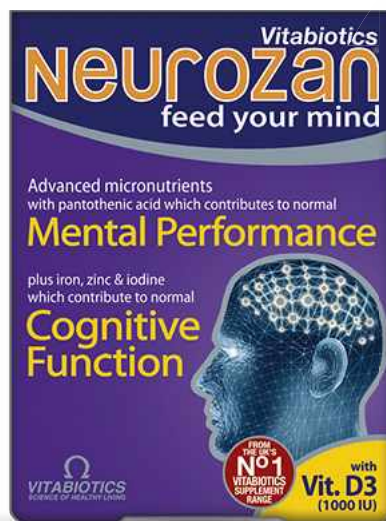
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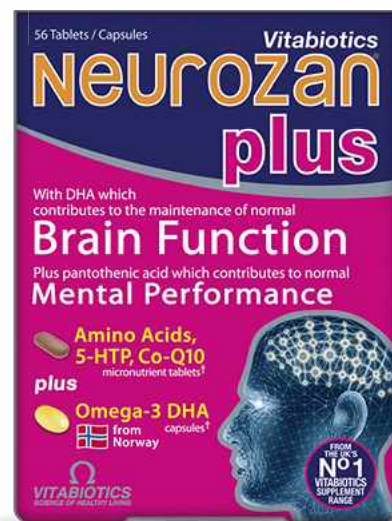
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VITABIOLOGICS
SCIENCE OF HEALTHY LIVING



EVERYDAY SCIENCE

HELEN CZERSKI

There is one reaction to thank for making toast taste so delicious

WHY BROWN? THAT'S the question I asked myself as I waited next to the toaster. Why does everything go brown when you cook it? Nothing goes green or red. The only things that don't go brown are foods that are cooked in the microwave.

Inside the toaster, the bread was absorbing heat. On the surface, molecules were jiggling around faster, bumping into each other more. Some of the tiny water molecules got enough energy to escape altogether, and floated off into the kitchen. I peered down at the bread, but I could only see that the surface was drier, so I left it alone and went to poke about in the kitchen cupboard for some jam.

Mostly, we don't think of ourselves as doing chemistry while we cook, but we are. The necessary ingredients for the chemical reaction are proteins (which are made up of building blocks called amino acids) and sugars. Left alone together they will react, although it takes months before anything noticeable takes place. But give them some heat energy to liven things up, and the molecules start to dance.

While I was on the hunt for jam, the amino acids and sugars in the bread were joining forces to create more complex molecules. Those large molecules are unstable, so many of them were breaking apart to produce a cascade of smaller ones. When I next looked, I could see some of the newer molecules because they were brown. The magic comes when the smallest chemical offspring are produced, because they have flavours and odours that the parent molecules didn't. I could smell the chemistry happening as I leaned over the toaster. This series of events is called the Maillard reaction, and its discovery was the first step in proper food science.

This one reaction is responsible for the deliciousness of brown crusty bread, golden biscuits, butterscotch and almost anything else you can think of that tastes better toasted or roasted. Caramelisation (oxidation of sugars) contributes a bit, but the Maillard reaction is king of the flavour world. We manipulate it almost without thinking, because changing cooking times and temperatures controls the flavour molecules produced.

My soon-to-be-toast was browning on the outside, but not the inside. This seems weird until you know that water holds the reaction back. The



"This one reaction is responsible for the deliciousness of brown crusty bread, golden biscuits and butterscotch"

outside dries out most quickly, and reaches the highest temperatures, so it browns the fastest. If I had brushed it with a slightly alkaline substance (not something I've ever done with toast, but it's what they do with pretzels), the reaction would have taken place faster.

Nothing browns in the microwave because to get a decent reaction rate, you need temperatures to be above 120°C. Microwaves heat liquid water, so they can't raise the temperature above water's boiling point of 100°C. Microwaved food is missing all the lovely flavour molecules that form during the Maillard reaction, making it a bit insipid.

Best of all, the reaction enables you to use milk as invisible ink. Use milk to write your secrets onto a piece of paper and heat it up slightly. As it contains proteins and sugars, you'll kick the Maillard reaction into action, turning your words brown. At that point, my nostrils reminded me you can

have too much of a good thing. The lovely flavour products were being replaced by the acrid pong of burnt toast and, sadly, I extracted the charred remains of my bread-based chemical reaction. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses*

SPECIAL
EDITION

YEARBOOK 2015

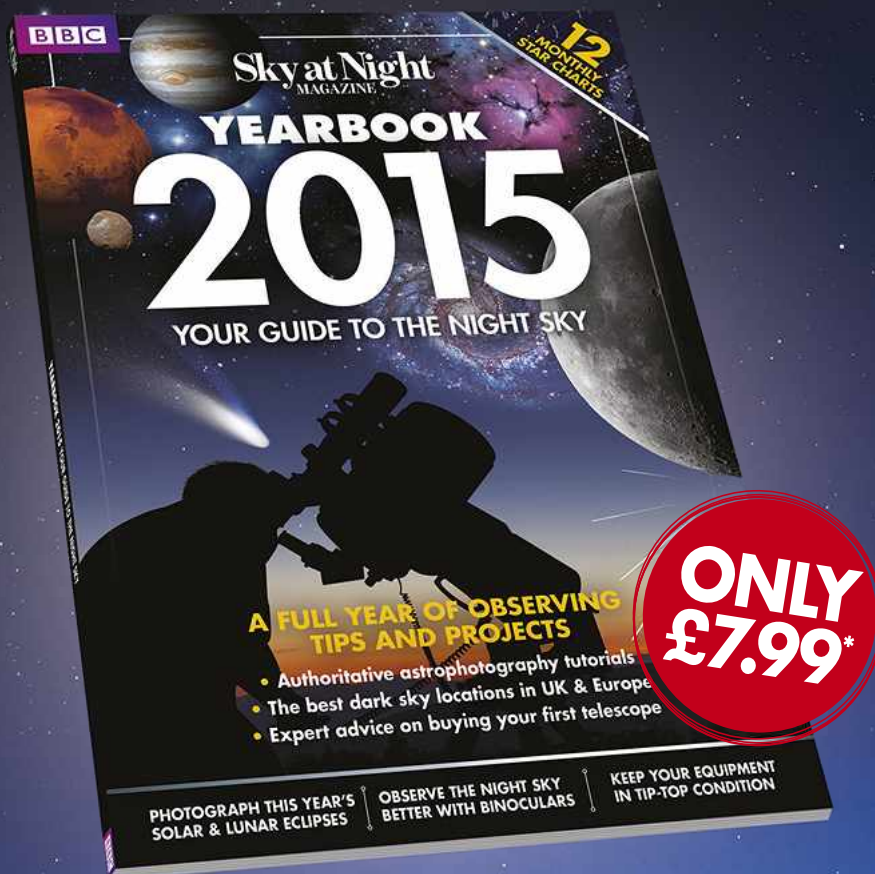
YOUR GUIDE TO THE NIGHT SKY

FROM THE MAKERS OF
BBC Sky at Night
MAGAZINE

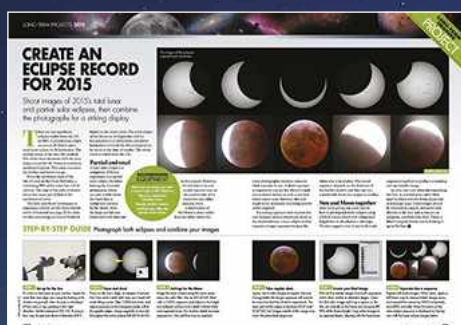
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INTO THE FUTURE

STEPHEN BAXTER

What did the Ice Ages ever do for us? Quite a lot, as it happens...

OUR UNDERSTANDING OF Ice Ages – ‘winters’ that lasted for millennia – has only been acquired over the past couple of centuries. We have learned that the advance and retreat of the ice has had a significant influence on the evolution of mankind – and may do so again.

In 1815, Swiss chamois hunter Jean-Pierre Perraudin noticed large boulders – known as ‘erratics’ – in a valley in the Swiss canton of Valais. He explained these as evidence of glaciers having once extended much further down the mountains than in the present. He wasn’t the first to notice this: the ‘father of geology’, James Hutton, had made similar observations 20 years earlier. But it wasn’t until the 1870s that geologists accepted the idea that the Earth has been repeatedly gripped by Ice Ages, when the polar ice caps spread into temperate zones and stayed there for millennia.

Today, the sequence of glaciations is thought to be primarily caused by ‘Milankovitch cycles’. These periodic variations in the Earth’s tilt and distance from the Sun redistribute the sunlight received across the planet’s surface, affecting the climate.

Over time, evidence has shown how glaciations may have given humans a helping hand. Dr Andrea Manica and colleagues of the University of Cambridge have developed the most recent version of the ‘climate pump’ theory – the idea that climate changes forced, or enabled, humans to spread across the planet. The earliest pumping may have been a warming period 70,000 years ago when vegetation invaded Arabian deserts, enabling humans to move out of Africa. Later glaciations, by lowering sea levels and creating land bridges, allowed humans to reach other continents. Australia became accessible some 60,000–40,000 years ago, while humans crossed the Bering Strait between Asia and North America 15,000 years ago.

Today, scientists speculate about glaciation on other worlds. In the 1970s, images of giant valleys and canyons on Mars led Carl Sagan to wonder if Mars is now locked in a glacial phase. If so, the planet could be terraformed relatively easily, perhaps by merely melting the water ice at its poles. However, Mars’s Ice Age is unending: the evidence of glaciation there is billions of years old, not thousands of years as on Earth.

The surface of Saturn’s moon Titan is perpetually frozen water ice, but methane and other hydrocarbons in the mostly nitrogen atmosphere



“Glaciations, by lowering sea levels and creating land bridges, allowed humans to reach other continents”

act as greenhouse gases, keeping the surface warm enough to support lakes of liquid hydrocarbons. But it may be that the methane is periodically depleted by reaction with other gases, causing global temperatures to fall, and the surface liquid to freeze out. Among the exoplanets (planets outside our Solar System) there may be even more exotic cycles of glaciation. In Brian Aldiss’s *Helliconia* novels, there is an Earth-like planet whose sun follows its own long elliptical orbit around a hot ‘supergiant’ star. Each ‘Great Year’ delivers centuries of tropical summer when the stars are closest, but Ice Age conditions when the stars are furthest apart.

Currently, we live in an ‘interglacial’ period that has lasted thousands of years – but all around us, invisibly, the Milankovitch cycles still operate. Arthur C Clarke’s haunting story *The Forgotten Enemy* describes the future abandonment of London: “Returning in triumph to the lands they had once possessed, the glaciers had come again”.

Perhaps the next time the ‘climate pump’ operates on our crowded world, it will impel us to leave the planet altogether. ■

STEPHEN BAXTER is a science fiction author who has written over 40 books. His latest is *Ultima*, published by Orion

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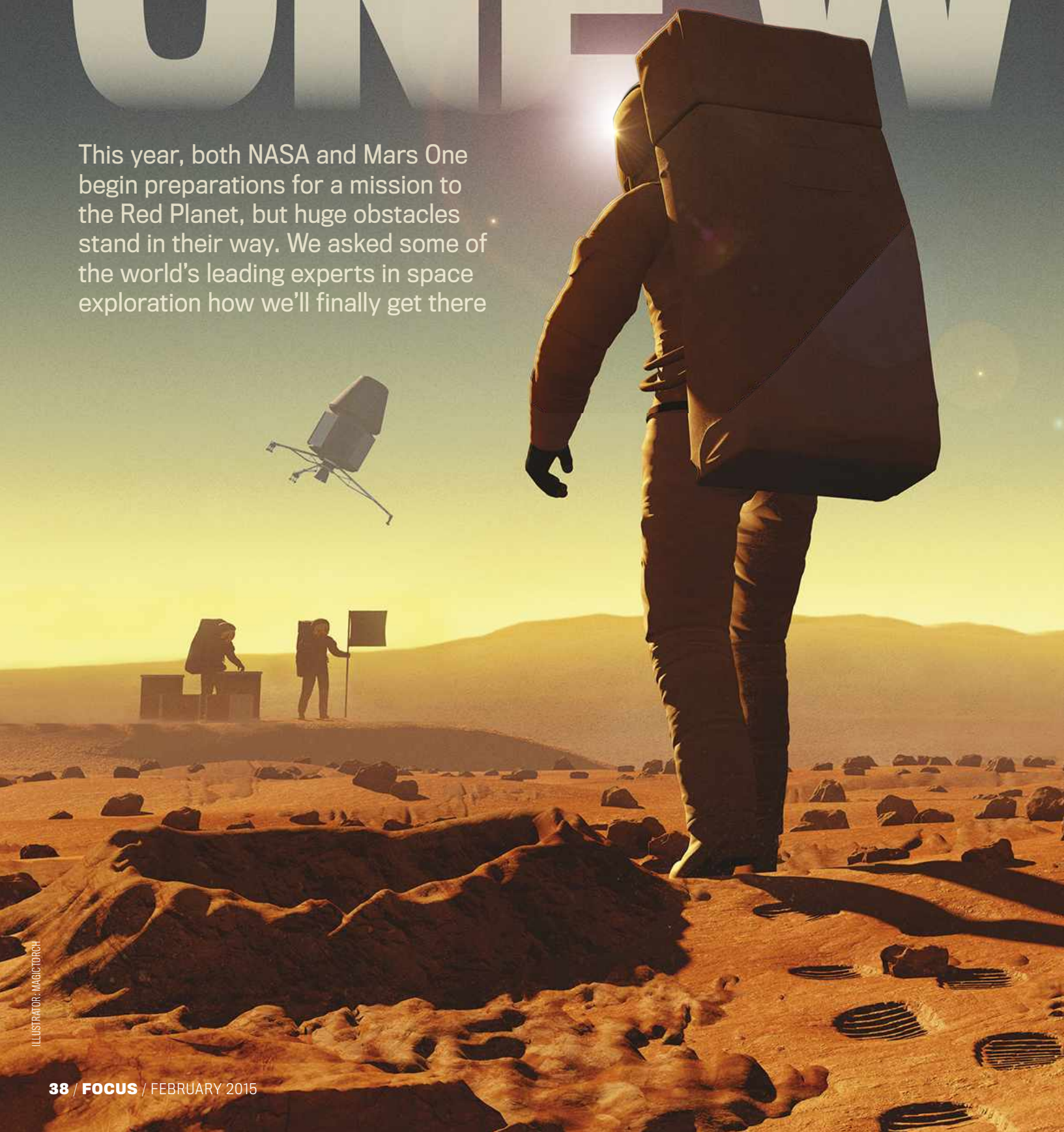


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ONE WAY

This year, both NASA and Mars One begin preparations for a mission to the Red Planet, but huge obstacles stand in their way. We asked some of the world's leading experts in space exploration how we'll finally get there



AY TO MARS



THE RACE TO Mars has begun. First out of the gate was the underdog: Mars One, a private company staffed by former NASA and ESA employees that plans to put people on Mars within 10 years. It's already started picking its crew. Now, NASA has shown its hand. In December, the US space agency began testing Orion, a spacecraft it says will be the first to carry humans to Mars.

As well as all that cold, dark space standing between us and Mars, there is a huge number of obstacles that both teams will have to overcome if we're to reach the Red Planet. How would we launch a colony ship? How would the human body cope? What if something goes wrong?

We put these questions to some of the world's leading experts on long-term space missions, in a bid to find out how we'll finally set foot on the Red Planet...



SELECTION



PROF SUZANNE BELL

Prof Bell works on NASA's Human Research Program, looking at the qualities needed in astronauts taking part in a long-term space mission. She describes the ideal Mars colonist

What kind of person would you pick for a mission to Mars?

IT GOES WITHOUT saying that working and living in such an extreme environment will require capable individuals who are highly compatible with each other. They'll be intelligent, fit, adaptable and stable, with great coping and teamwork skills. But there are some other considerations that are more nuanced.

It's no surprise that introverts do better in isolated and confined spaces: the isolation and the social monotony of space require a certain level of introversion. At the same time, there is a level of social warmth typically associated with extroverted individuals that would be beneficial, as team members rely on one another for social support. So how can this paradox be managed? Well, in this case you can have the best of both worlds - ambiverted individuals have qualities of both introversion and extroversion. They're also likely to have the

middle-of-the-road personality that can most easily adapt to the unique demands of long-duration space exploration.

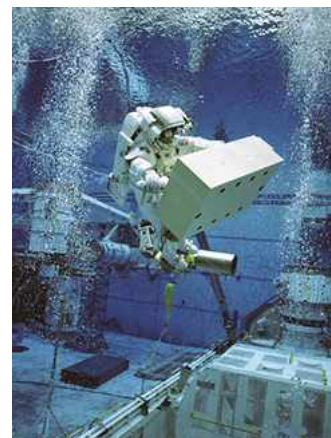
I'd also look for team members who are high in self-monitoring - that's the ability to show concern for, and appropriately modify, your behaviour in a social situation. Have you ever been in a meeting, wanted to say something, and then thought to yourself, "It's not very important that I say this right now"? If so, you were self-monitoring. High self-monitors consider social cues in the situation to determine appropriate action. They're better at attending to status dynamics in relationships and can adapt their behaviours accordingly. This will help keep conflicts manageable, and help the team effectively negotiate the status and power issues that are likely to come up in the new settlement.

Of course, going to Mars is a risk, but you won't want someone who is too much of a risk-taker: some people take risks because they haven't appropriately weighed up the consequences. Living and working in a hostile environment means that one small mistake could have major consequences; it could even mean the death of the team. So the right person will be able to be careful and responsible in their actions, yet still have a great sense of adventure.

Ensuring team members have shared values is also critical to their compatibility. Personal values are ordered in terms of relative importance, and they drive behaviour - particularly when faced with competing priorities. The team that is sent is likely to be diverse in a number of areas. Shared values are critical for bridging these differences. For example, the team may have a mix of scientists and non-scientists (such as the pilot). When the team is faced with a situation that presents competing priorities (for instance, whether to lose data or preserve equipment), the team will more easily agree on a course of action if they have shared values.

How would you prepare someone for a one-way mission to Mars?

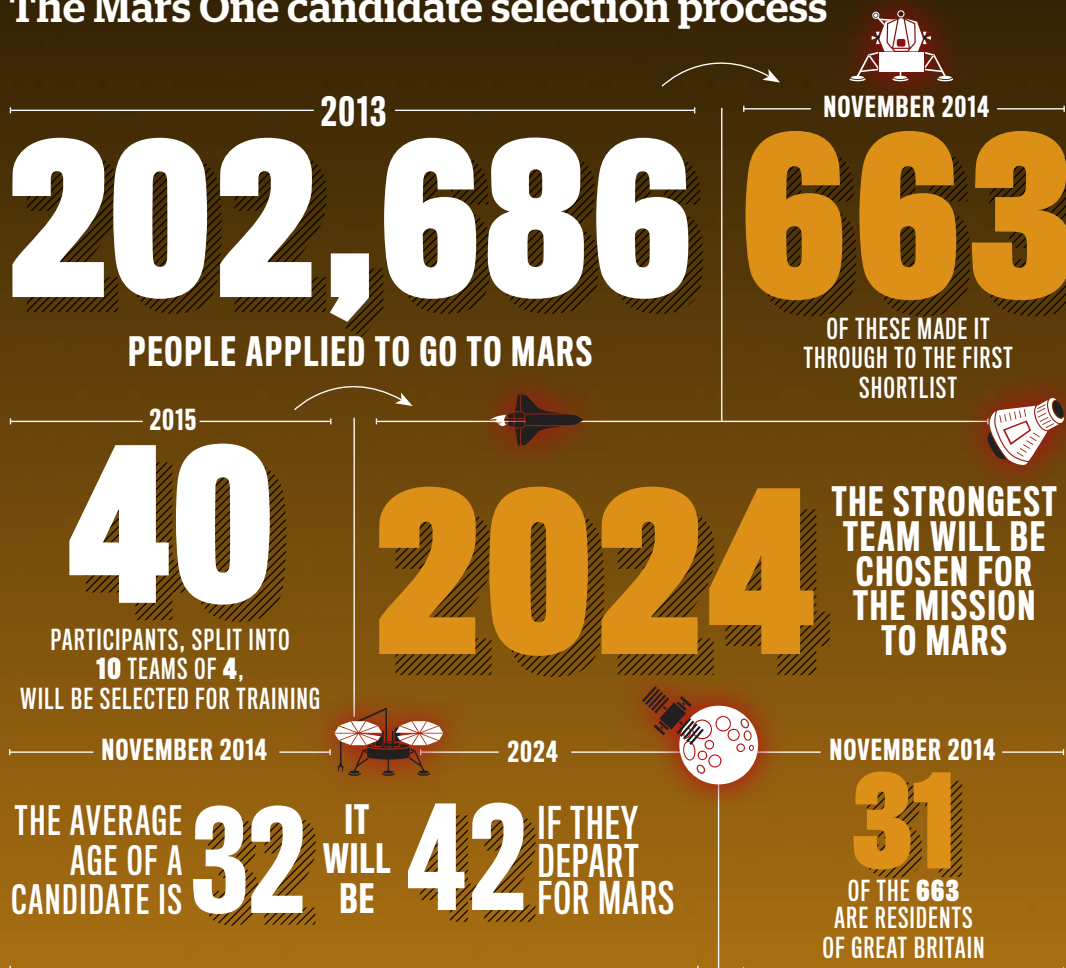
Preparation will involve extensive training, and ensuring that the team has accepted agreed procedures and standards. Training will need to include obvious knowledge and skills (how to land the spacecraft) as well as everyday activities that aren't quite so simple in space (how to go to the bathroom in zero gravity). Teams also will need to



While on Earth, astronauts train underwater to mimic the lower gravity found in space

"Even the most carefully selected, emotionally stable team members will struggle with the extreme isolation at some point. The team will need to be trained in coping skills"

The Mars One candidate selection process



Maggie Lieu

Age: 23

From: Coventry

Profession: PhD candidate in astrophysics

Why did you apply?

It's always been my dream to work for NASA, but it seemed like privatised space travel would become important in my lifetime. I didn't know about the project until the deadline, so I threw together a video on the day and just applied.

What did being selected feel like?

It was surreal. I looked up Mars One and it was more serious than I'd thought. I told my mum I had been shortlisted and she just said, "yeah okay". I got a call a few weeks later when she saw me in the newspaper – she didn't realise it was real. It gets more real every day.

What do you think it will feel like to step on to Mars?

I don't think anyone knows. Every day more and more people are telling me that I'll get selected. If I actually go to Mars, I think it'll feel like a massive relief. I'll finally realise this incredible dream.



Lewis Pinault

Age: 54

From: Twickenham

Profession: Innovation Delivery Executive and Researcher, UCL/Birkbeck Centre for Planetary Sciences

Why did you apply?

I believe it's possible to get to Mars safely using existing technologies. We'll be the data – the crew psychology, the effect of radiation and the impact on the human body.

What did being selected feel like?

Good. It sounds arrogant, but I wasn't wildly surprised. When I put in my application I was about to join an Antarctic research programme, and I knew my background in planetary geology would fit in with their plans.

What do you think it will feel like to step on to Mars?

I dream about it sometimes. I remember the photos from when the first Viking landers touched down on Mars in 1976. It was a rich orange colour with a salmon pink sky. Now we know it looks more brown and the sky is more opalescent. When I dream about it, I see both.

be trained in several areas critical to the team's self-sufficiency: learning how to learn, coping skills and teamwork skills. The needs of the settlement will likely change over time and unanticipated events will occur. It's critical to have not only intelligent team members but also those who can evolve; for example, those who can self-regulate their learning. Self-regulation is thinking about thinking, using strategic action to learn. There's no human with the perfect skillset for life on Mars: some kind of pilot-cum-farmer-cum-doctor. But if we can teach a candidate to teach themselves, to adapt, to evolve, then they'll have the toolset they need to survive. For example, an astronaut who can identify precisely what part of the landing procedure they're getting wrong, and the training they need to correct the problem, will be more valuable on a long-term mission.

Even the most carefully selected, emotionally stable team members are likely to struggle with the extreme isolation at some point. The team will need to be trained in coping skills – how to identify and respond to difficulties in coping, and strategies for providing support.

Although training will be key to team preparation, many issues will be best resolved with agreed-upon standards. Individuals from different backgrounds may have different views on living standards, personal hygiene or even the treatment of women. Making sure everyone is on the same page regarding these issues can be used to keep conflicts at a manageable level.



SPACECRAFT



PROF MASON PECK

How will we get to Mars? Prof Peck, former Chief Technologist at NASA, outlines Mars One's plans for getting to the Red Planet

How would you send a crew to Mars?

THE FOUR-PERSON crew will travel to the Red Planet in a transit vehicle – a small space station that will be assembled in low Earth orbit before the crew arrives. In-orbit assembly allows us to build large space systems, like the International Space Station (ISS), that we're unable to launch intact from the Earth, for technical or financial reasons.

Once the crew is onboard, the transit vehicle will fire its engines and begin its journey to Mars. This will be the astronauts' home for seven months, and they'll eat, sleep and train in the vehicle's habitat module. Then, when they're near Mars, they'll enter a separate lander module, reminiscent of the Apollo landers.

The one-way journey needs less than half the supplies of a round trip. They'll have enough water and oxygen onboard to last them for the whole journey, as well as plants to grow more food should they run out. The transit vehicle will also have an environmental control and life support system (ECLSS) to control air pressure, detect fires, monitor oxygen levels and manage water and waste, but

this won't need the longevity of existing ECLSS's like that found on the ISS. This reduces the hardware costs involved.

A key feature of Mars One is its use of existing technologies, in contrast to the usual practice of creating a custom-built spacecraft for every mission. So no new launch vehicle will need to be designed for Mars One. Instead, the four-person crew will be carried to the orbiting transit vehicle by a pre-existing system such as SpaceX's Falcon Heavy. It'll be a similar approach to the way astronauts travel to the ISS today.

We'll continue sending four-person crews to Mars at every launch opportunity – roughly every 26 months, when Mars and Earth align in a way that minimises the propellant necessary to make the trip. As more colonists arrive, the first Martian settlement will begin to take shape.

How will you land on Mars?

Landing won't be easy. NASA's analysis predicts that a successful six-person mission would need to land 40,000kg on the Martian surface. Mars One's mass will be lower because of its smaller crew, but still, the largest payload delivered to date is just 1,000kg (the Mars Science Lab mission, which landed the Curiosity rover in 2012). This leaves quite a few challenges ahead for Mars One.

Fortunately, NASA's previous successes and investment in future technologies should provide us with a solution. One possibility is aerocapture – slowing the vehicle down by sending it through the Martian atmosphere. This would create a drag force, reducing the craft's orbital energy. Secondly, inflatable aerodynamic decelerators might be used. Currently in development, these expand to create a large, lightweight, heat-resistant body that further slows the vehicle.

Some rocket companies are also looking into landing vehicles through retropropulsion – the Buck Rogers technique of firing rocket engines in front of you to slow yourself down. SpaceX and NASA recently agreed to share data on supersonic retropropulsion gleaned from a launch of SpaceX's Falcon 9 in September 2014. This technology can be tested here on Earth, replicating Mars's atmospheric conditions by performing experiments at just the right altitude. It'll be a combination of these technologies that will allow the Mars One lander to reach the surface.

Will you need other support missions?

Absolutely. One strength of the Mars One concept is its focus on infrastructure – it's not just a one-shot, single-purpose mission. In 2018, six years before the first crew's departure, two communications satellites will be launched – one around the Sun and one around Mars – allowing constant communication between Mars and Earth. Laser communications, a new NASA-developed technology, will increase data-frequency transmissions. A demo mission around this time might also test some of the landing procedures.

"We'll continue sending four-person crews to Mars at every launch opportunity – roughly every 26 months"



NASA's Orion spacecraft, currently in development, is its flagship vehicle for future Moon and Mars missions

From 2020 through to 2024, there'll be a further series of preliminary missions to carry out some prospecting around the landing site, set up the area for human habitats and collect resources such as regolith, oxygen and water. These initial preparations will mean the first colonists have somewhere to rest and recuperate when they do finally arrive on their new home planet.



The Mars One crew will be launched into space on a SpaceX Falcon 9 rocket



MARS ONE TIMELINE

If all goes according to plan...

2018

An unmanned demo mission is launched to test the landing procedures on Mars. Two communications satellites are also sent into orbit, providing constant communication between Earth and Mars.



2020

A robotic rover is launched. Once it has arrived on Mars, the rover drives around to find the best location for a settlement. It then prepares the surface for the arrival of the next missions.



2022

The first cargo missions are launched. These carry essential items such as food and solar panels, as well as inflatable living units and equipment to generate water, energy and breathable air.



2023

The rover sets up the outpost before the arrival of the settlers, connecting the modules, deploying the solar panels and depositing Martian soil over the living habitats to provide radiation shielding.



2024

The first Mars One crew begins the journey from Earth. They are the first humans to embark on a mission to Mars.



2025

The crew members touch down on the Red Planet. After leaving the lander in Mars suits, they're taken by the rover to the prepared settlement. Here, they have time to acclimatise before finishing the setting up of the settlement.



2026

The second four-person crew launches from Earth, landing in 2027. This process repeats roughly every 26 months, and so the colony grows.



WELLBEING



DR KEVIN FONG

Dr Fong has worked with NASA and is author of *Extremes: Life, Death And The Limits Of The Human Body*. He explains how the body will cope with life on another planet

If you were the doctor on a trip to Mars, what would you be most worried about?

A MARS MISSION crew doctor will have their work cut out. Prevention is always better than cure, so keeping the crew healthy by making sure they eat the right diet, stick to an exercise programme and generally take care of themselves would be important. But a crew physician would be responsible for providing healthcare should any medical emergency arise. With space and power at a premium, and the physician having to be everything from general practitioner and casualty doctor to anaesthetist and surgeon, that would be a tall order. And there's plenty up there in the way of threats: the effects of weightlessness, the risk of decompression illness during space walks, the intense radiation outside the protection of Earth's magnetic field, and micrometeoroids.

The biggest threat to life, though, is not disease or even traumatic injury. Astronaut crews are screened to make sure they're in peak condition, and the spacecraft itself and all activities that take place within it are designed to expose the crew to the lowest possible risk of injury. Day-to-day life would be far safer than in the average house: you can't fall down a flight of stairs, it's hard to start fires and it's nearly impossible to electrocute yourself. Instead, what would most worry a doctor would be being part of a crew that's hurtling through space, powered by rockets with the explosive potential of a small nuclear missile.

It's not the medicine you need to worry about, it's the rocket science. We've never lost part of the crew on a space mission: either the engineering works and everybody lives, or it doesn't and everyone dies.

What would happen to the human body after a year on the Martian surface?

Mars doesn't support life any better than the empty space that the crew would have crossed to reach it. It is smaller than Earth and further from the Sun, with a thin atmosphere composed almost entirely of carbon dioxide. So when crews arrive there, they will be completely dependent upon a suite of life support systems, and forced to live in habitats that are suitably shielded from radiation. But the aspect of Martian life that will shape physiology more than any other is the reduced gravity.

Astronauts living on Mars will experience roughly one-third of the gravity that they would on Earth. We already know, from more than 50 years of human space flight, that

weightlessness has effects on the human body. Bone and muscles waste rapidly and the heart, which is itself a muscle, deconditions. But other systems are also affected. Hand-eye coordination becomes impaired, the immune system becomes suppressed and astronauts can become anaemic. Prolonged weightlessness can take athletes and turn them into couch potatoes very quickly.

What we don't know for sure is how severe these effects will be on Mars. On the Red Planet there is at least some gravity but it's unclear if it's enough to protect the astronauts' biology. Over the years, we've studied hundreds of people who've spent time floating weightlessly but only 12 people who've ever experienced reduced gravity on the surface of another world: the Apollo crews who landed on the Moon. And that's left us without enough information to know for sure how severe the problem of life on Mars, at one-third of Earth's gravity, will be.

For now, a combination of drugs, controlled diet and strict exercise regimes will be what crews rely upon to ward off the deconditioning effects of living on a world with reduced gravity. Though some authorities have proposed the use of short-arm centrifuges, with radii of around 3m and rotation rates of 40rpm, to provide a short burst of artificial gravity at the surface, the right answer isn't yet known. But what's clear is that the exploration of our nearest planetary neighbour will also prove to be an exploration of the limits of the human body.



"For now, a combination of drugs, controlled diet and exercise regimes will be what crews rely upon to ward off the deconditioning effects of living with reduced gravity"



Exactly how the low gravity conditions on Mars will affect long-term settlers remains, so far, unknown



Diego Urbina training as part of the Mars500 mission, which simulated a manned Mars voyage

COLONISATION



PROF CHARLES COCKELL

Prof Cockell is director of the UK Centre for Astrobiology. His lab investigates life in extreme environments. Here, he explains what life will be like for the Red Planet's first inhabitants

What will the first few days on Mars be like?

THE NEW SETTLERS' first priority will be putting in place the basic essentials for survival, and ensuring that backup systems are fully functioning. They'll have a lot on their minds. They'll need to ensure that all oxygen production and recycling equipment is working, and if they're topping up their oxygen from water gathered from the atmosphere (by breaking it down using electrolysis), they'll need to check that the extractor fans collecting atmospheric water are up and running. In the first weeks, the colonists' food will not be home-grown. They'll be eating dried and preserved rations in boxes. However, they may spend the first two weeks setting up a simple greenhouse so that they can begin to grow food as soon as possible.

A crucial matter for survival is energy. Whether they're using nuclear or solar energy, they'll need to set up the apparatus, link it to the base and make sure that the power supply is stable and reliable. They may also set up chemical apparatus to make useful things like fuel. Carbon dioxide in the atmosphere, for instance, can be reacted over a catalyst with hydrogen (itself released from water gathered from permafrost or the atmosphere) to make methane fuel to power their robotic rover.

The Sun produces infrequent, but intense, particle streams that can cause severe radiation damage. So the settlers will need to ensure that radiation shielding is in place – a layer of Martian rock or water in the walls of their habitat would do the job – and that they have a more resistant shelter to escape to during periods of intense radiation.

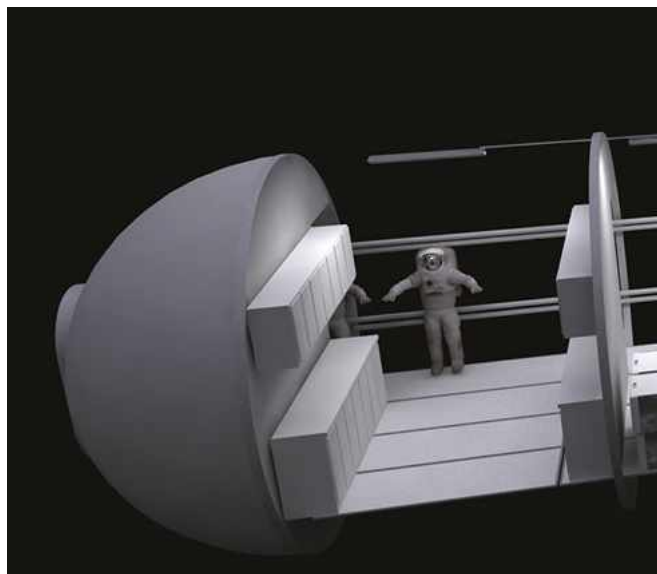
Most of these procedures will have been tested before they land, so in principle it should just be a matter of plugging in the equipment. But they will still need to check and cross-check all of these systems in a

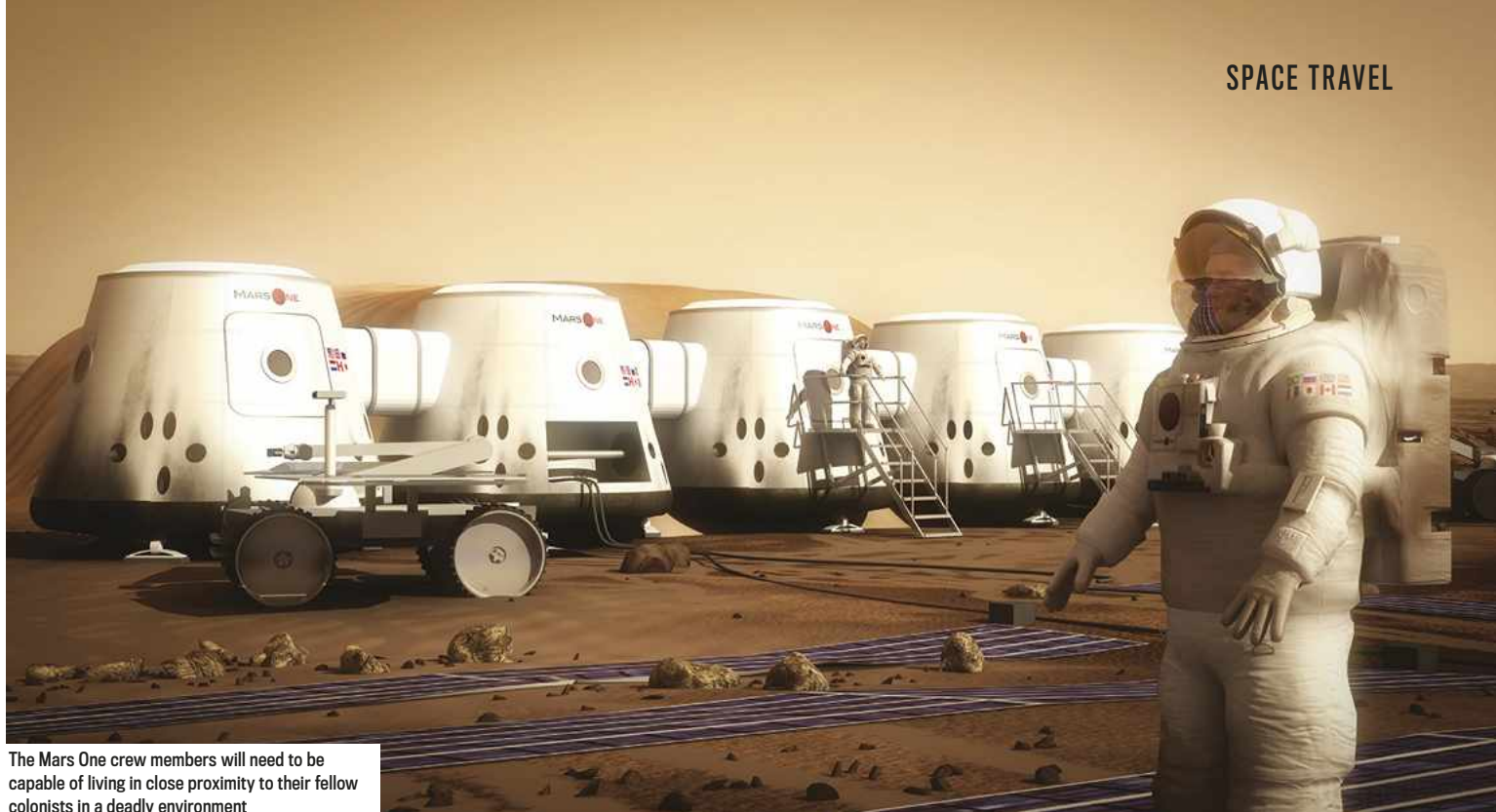
potentially lethal environment. The first few days will be a Lego-like frenzy of putting together the first Martian base.

What might a typical day on Mars involve?

Once they're settled in, the colonists can begin to plan their days. Before breakfast every morning, they'll check key systems to make sure everything's functioning well. The most important activity of the day will be a morning briefing about the day's activities. Maybe they'll be staying at home to repair some crucial system or study their data. If not, they'll need to prepare themselves for a day in the field.

Donning spacesuits, they'll head out into the Martian landscape on foot or in a rover,





The Mars One crew members will need to be capable of living in close proximity to their fellow colonists in a deadly environment

studying the planet's geology to learn more about how Mars was formed, and what this might tell us about the Earth's formation. They might look for ancient signs of life to find out if Mars was ever inhabited – and if not, why a planet that was a little like the Earth in its early years remained dead, while our own planet became covered with thriving microbial life. They might also go on reconnaissance missions to scout for useful resources, or locations for future stations. They could spend days away from the settlement, living and eating in their rover.

With every day that they live on Mars, their confidence and knowledge will grow – and with it, the knowledge of the human species as a whole.

What will the colonists need to think about beyond simple day-to-day survival?

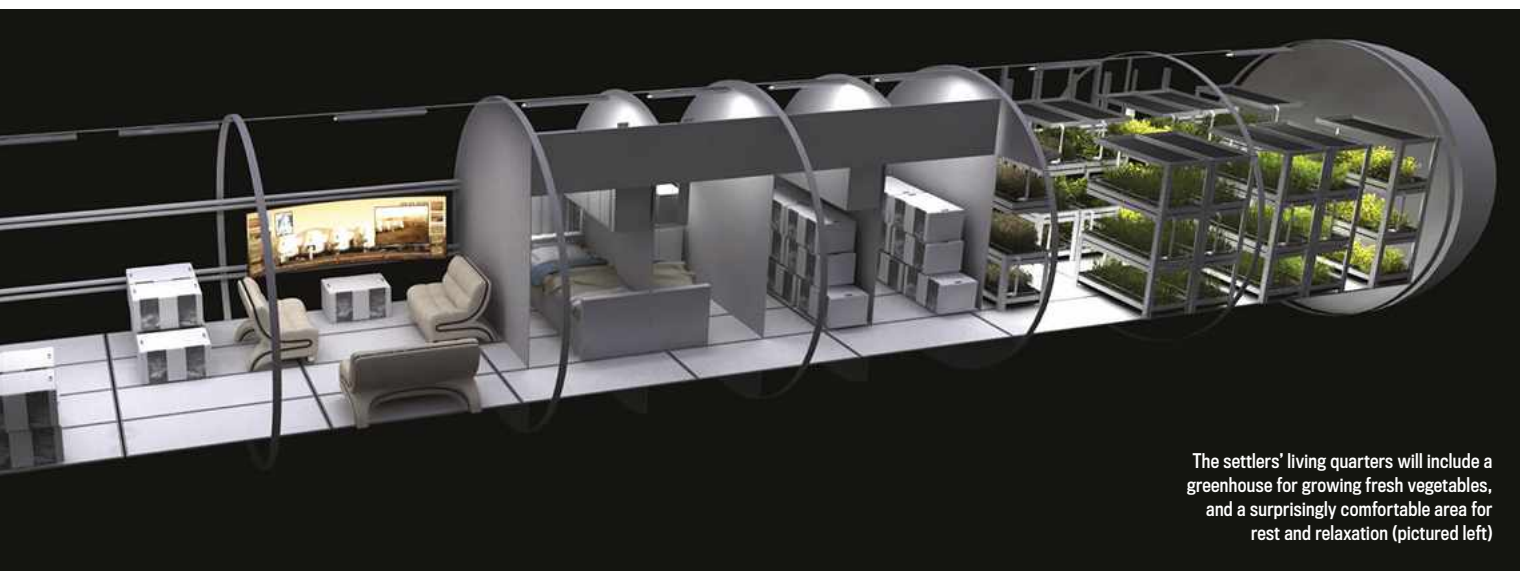
Beyond the science and planning there is the human story. These explorers will inhabit a deadly environment, trapped in a tiny space with their fellow colonists. Their challenges will come not just from the outside (the Martian environment), but also from the inside – this is what we call the human challenge.

Professionalism and good behaviour will get them a long way as they learn to work together and carry out their mission, but other things will help. For instance, they'll have small spaces in the station where they can spend time on their own, write messages to loved ones on Earth, paint or read.

We know from the accounts of those who've lived on space stations that growing crops and tending to other creatures helps a great deal, by giving people psychological reprieve from the extreme environment. Looking after animals and plants will provide the settlers with food, but it might also be a good therapeutic hobby.

Mars won't all be work. The colonists may go out on treks to explore the planet just for the fun of it. Maybe as their technical capacity improves they'll attempt daring transpolar crossings of the great polar ice caps, or set out on long-duration expeditions across the formidable Martian deserts.

In the long-term, they'll need to find a way to manage their affairs in a more organised way. As a small group, direct participatory democracy will probably work, but as numbers grow they may need some formal constitution by which to govern themselves. It'll be the first extraterrestrial government. ■



The settlers' living quarters will include a greenhouse for growing fresh vegetables, and a surprisingly comfortable area for rest and relaxation (pictured left)



What will our world look like when futuristic tech becomes a reality?
Duncan Graham-Rowe investigates

NEW TECHNOLOGY eventually blends in to our everyday lives. Smartphones as we know them today simply didn't exist 10 years ago, yet now there's one in virtually everybody's pocket. So how will coming technologies change the way we live? The

designer Fernando Barbella gives us a glimpse of tomorrow's world in his blog, *Signs From The Near Future*. The signs, displayed on streets, vehicles and inside buildings, are a new twist on familiar scenes. Read on to find out when Barbella's signs might be part of the landscape.

FORGET MESSING AROUND with rockets to get into space. Instead, imagine getting into a lift on the ground, which then ascends through the atmosphere and up past geostationary orbit to a spaceport.

With a 'space elevator', vehicles climb up a vertical cable. The cable is anchored to the ground at one end, somewhere near the equator. The other end extends up and out, and is attached to a free-floating spaceport. This is potentially cheaper and

safer than the usual rocket-based methods of space travel. Constructing a space elevator would cost between \$10-25bn (£6-16bn) and take about 10 years to build, according to Ted Semon of the International Space Elevator Consortium. The main challenge, says Semon, is finding materials that are sufficiently strong and light to build a 50,000km-long cable. "Carbon nanotubes are the leading candidate, but there are other possible options including carbyne, graphene and boron-nitride nanotubes."



SMART GLASSES FUSE wearable computers with head-mounted optical displays, creating a mobile interface that allows digital information to be mapped onto the real world that you see before you.

The technology is dubbed as the ultimate augmented reality, and is seen today in the form of the £1,000+ Google Glass. The question is, is it here to stay? While

undeniably attractive, the device relies heavily upon voice recognition (VR) software. Although VR has improved over the years, people tend to get annoyed when it gets things wrong, which is often. Considering the privacy and surveillance concerns that come with wearable cameras, along with the safety issues of being continuously distracted, we may start to see signs like the one below in all sorts of locations.



PHOTO: ISTOCK, FERNANDO BARBELLA



WOULD YOU BE willing to hop into a driverless taxi? Thanks largely to companies like Google, autonomous cars are becoming a reality. In some UK cities, that reality is going to happen sooner rather than later. This March, Milton Keynes is planning on introducing driverless taxi 'pods' to its network of cycle lanes. Meanwhile, Business Secretary Vince Cable announced plans to roll out a £10 million driverless car trial in four UK locations, with tests kicking off from

January. See our article on p54 for more on how the technology works.

So should we be worried? Far from it: the reality is that roads filled with autonomous cars promise to be far safer than those with humans at the wheel. The vehicles can potentially react far faster than humans, and their ability to do so makes it possible for speed limits to be increased. This also means that safety distances between cars can be reduced. Both of these factors should lead to less congestion and shorter journey times.

Driverless pods will soon be hitting the cycle lanes of Milton Keynes





THE MOVIE *INTERSTELLAR* showed astronauts cryogenically frozen as they were carried beyond our Solar System. In reality, the most promising method of cryogenically freezing mammals requires all blood to be removed from the circulatory system and replaced with a chemical solution, before putting the body on ice. It's not clear whether cognitive brain function would survive. So NASA is looking at a less extreme approach, which wouldn't involve making the subjects clinically dead. Instead, a state of deep sleep or 'torpor' would be induced. NASA's research will assess the feasibility of a suspended animation chamber for future Mars missions.

For those trying to cheat death by buying freezer space in the hope that a cure for their ailments will one day be found, there's a catch. Even if a remedy does emerge, it's still not clear how the body can be safely defrosted without damaging it.



JET PACKS HAVE long been saving the day in films – memorably the James Bond movie *Thunderball*. This popularity has given them a perpetual status as a must-have technology of the future. The trouble is, we have been keenly awaiting this form of transport for more than half a century. So what gives? One of the main problems has been range. Jet packs typically only run for about 30 seconds, which is barely enough time to take-off before landing becomes a priority. But that's changing. In 2016, the New Zealand firm Martin Aircraft Company plans to bring out a commercially available jet pack that can fly for 30 minutes. "Our company's first target market is the First Responder [emergency] sector," says Peter Coker, the company's CEO. The trick comes from moving away from a traditional rocket design towards petrol-powered turbines. Now the main hurdle is regulation rather than technology. "One of the biggest challenges will be in getting the regulatory authorities comfortable with its operation and versatility of use – it is effectively a 'motorbike in the sky,'" he says.



BITCOIN IS A digital currency or, more accurately, a digital cryptocurrency infrastructure that already exists and works. Although not yet widespread in the physical world, a number of restaurants accept Bitcoin, along with other retailers and businesses. Payment is as easy as bumping two smartphones together.

But why would we want or need Bitcoin, especially when its value fluctuates so wildly? It all comes down to who controls the currency. British Pounds and US Dollars

are effectively controlled by nations, but Bitcoin is based on a peer-to-peer infrastructure, which means there's no equivalent of the Bank of England or the Federal Reserve. 'So what?', you might think. Consider that the global economy is still recovering from the worst recession since World War II, due in part to the risky behaviour of bankers. Bitcoin offers an alternative currency that is neither tied to bankers nor nations. Some argue that the more that people use it, the more stable a currency it will become.



PHOTO: FERNANDO BARBELLAX2, ISTOCK, PRESS ASSOCIATION X2



Lab-grown meat could feed a swelling global population



The Cultured Beef burger tasted just like real meat

WHAT ABOUT A technology you could really sink your teeth into? Synthetic meat may not seem very appetising at first. But let's face it, the meat industry is already highly processed and research suggests that it is not sustainable in the long term. Meat has one of the largest carbon footprints of any food, while global population growth raises serious concerns about how demand for meat can be met in the coming decades. Synthetic meat, created from cells taken painlessly from a single cow, could produce 175 million burgers. This would normally require 440,000 cows, says Prof Mark Post, who led the Cultured Beef effort at Maastricht University in 2013 to create the first ever synthetic burger. "The cells grow into strands of small meat fibre and 20,000 of

these are then combined to create one normal sized hamburger," he says. "It is biologically exactly the same as the meat tissue that comes from a cow." But it will still take at least a decade or two for the price to come down. The Cultured Beef burger came in at a cost of €250,000 (£200,000), which is far more than most people would be willing to fork out. ■

DUNCAN GRAHAM-ROWE is a scientific editor at Gavi, The Vaccine Alliance




To see more of Fernando Barbella's work, visit his blog at signsfromthefuture.tumblr.com



HANDS-FREE

PHOTO: VOLVO



On 1 January, it became legal to test driverless cars on the UK's roads. **Jamie Merrill** finds out how the latest generation of autonomous vehicles is coming along...

WHAT IF, INSTEAD of wasting time sitting in traffic, we could work behind the wheel, grab a snack or even take a nap? What if our cars didn't even have steering wheels?

This year, that dream may come one step closer to reality, thanks to a change in The Highway Code that will allow self-driving cars to take to British roads. British engineers, including the RobotCar UK team and a group led by Arup in Milton Keynes, are experimenting with self-driving cars. Other tests will be taking place in Coventry, Bristol and London.

The change in the law has already got engineers and academics excited, with the likes of Dr Kevin Curran, a senior member of the Institute of Electrical and Electronics Engineers, predicting the end of traffic jams and minor bumps as we all enjoy the benefits of 4G connectivity and zoom about in pod-style vehicles.

RACE FOR PROGRESS

Despite a strong skills base in robotics and big data, the UK is still, in some ways, at the back of the grid in terms of driverless car testing. In California, however, Google has been racing ahead. The search giant's driverless cars have clocked over a million kilometres on the open road with just one accident – and *that* occurred when a human took over from the computer. In Sweden, the city of Gothenburg has granted Volvo permission to test 100 driverless cars from 2017 in a project called Drive Me. In Japan, Nissan carried out the country's first public test in 2013, while China holds a driverless car competition each year. ➔

ANATOMY OF A DRIVERLESS VEHICLE

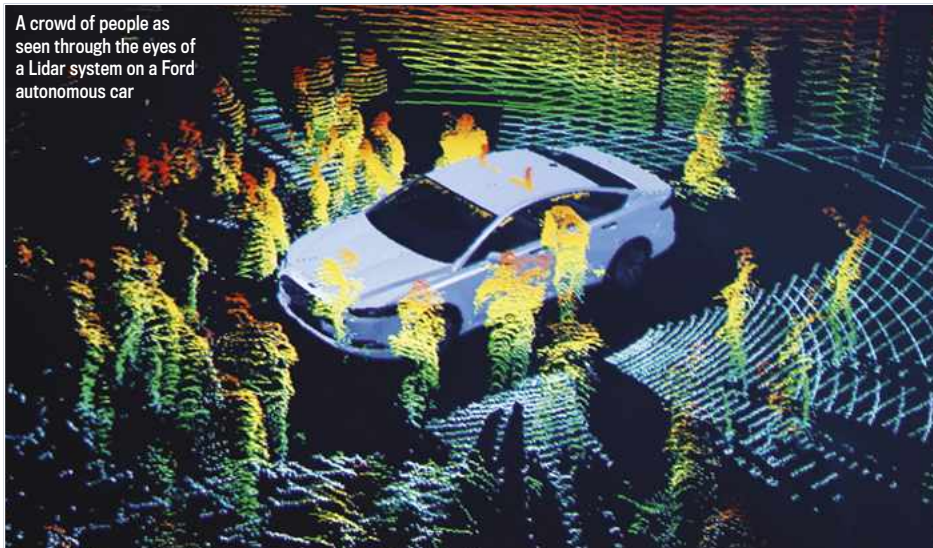
PROBABLY THE MOST advanced driverless car project in Britain is RobotCar UK. Led by Prof Paul Newman, it's based on an industrial estate outside Oxford. Rather than take the Google approach – spending up to £100,000 on numerous sets of sensors per car – it's fitted a small laser pod and a laptop to a standard Nissan Leaf electric car.

The hardware is simple and costs less than £3,000. Unlike other systems, RobotCar UK doesn't rely on expensive peer-to-peer communication with other vehicles or GPS navigation.

Instead of being truly autonomous, the RobotCar system learns. It scans its surroundings up to 1,000 times per second as you drive around. In doing so, the system builds up a complex 3D model of its environment, eventually allowing it to take control.

In the long run, the idea is that your car would learn not just from its own journeys but from every other similarly equipped vehicle. Your car would download the sum-total of knowledge before you set off, allowing it to react to recent changes in road layouts.

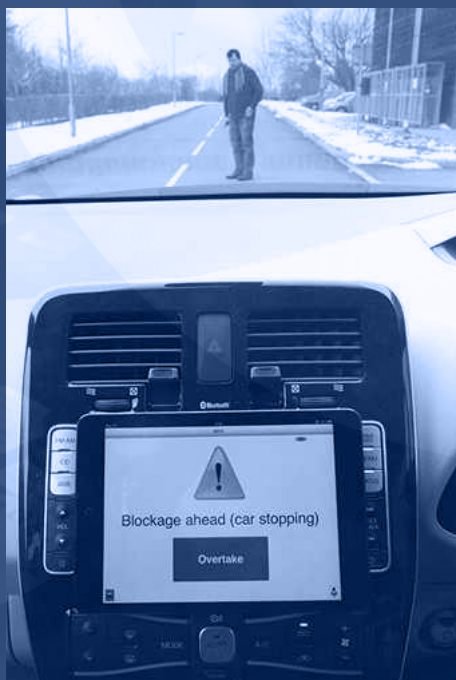
A crowd of people as seen through the eyes of a Lidar system on a Ford autonomous car



In the UK, the main issues have been how autonomous cars should be regulated to ensure the driver can take control in an emergency, and how a vehicle with no driver should operate. In California, where the roads are wide, there are no roundabouts and the weather is mild, this has been fairly easy to test. But in Britain the winter weather can switch between fog, snow and sunshine in a few hours. And then there are roundabouts,

“What’s more of an unknown is how people will react to them”

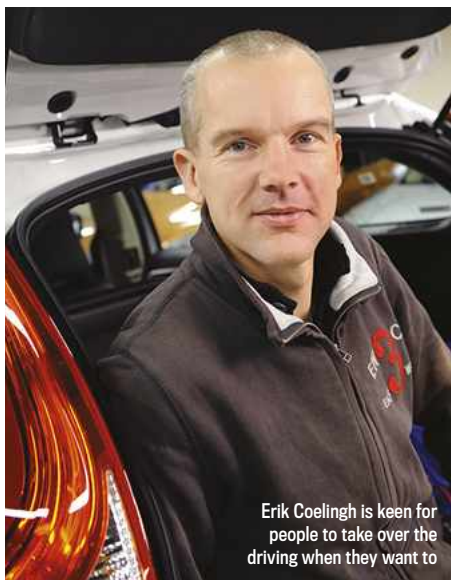
Prof David Lane, of UK Robotics and Autonomous Systems Special Interest Group, on driverless cars



potholes, country lanes, gridlocked urban traffic and gyratory systems to consider.

“The first test will be on quiet roads in good conditions. Once we understand how the technology works in the real world, and more importantly how people interact with it, we can extend the trials,” says Prof David Lane, who is chair of the UK Robotics and Autonomous Systems Special Interest Group. “We already have autonomous vehicles in the oceans and flying above us. The technology is reliable; the failures don’t happen because of poor technology. What’s more of an unknown is how people will react to them,” he continues.

To researchers like Prof Lane, fears over accidents are misplaced. “Traditional cars already knock people down and have accidents, and of course that will happen with autonomous cars. But, I’d wager, an awful lot less,” he says.



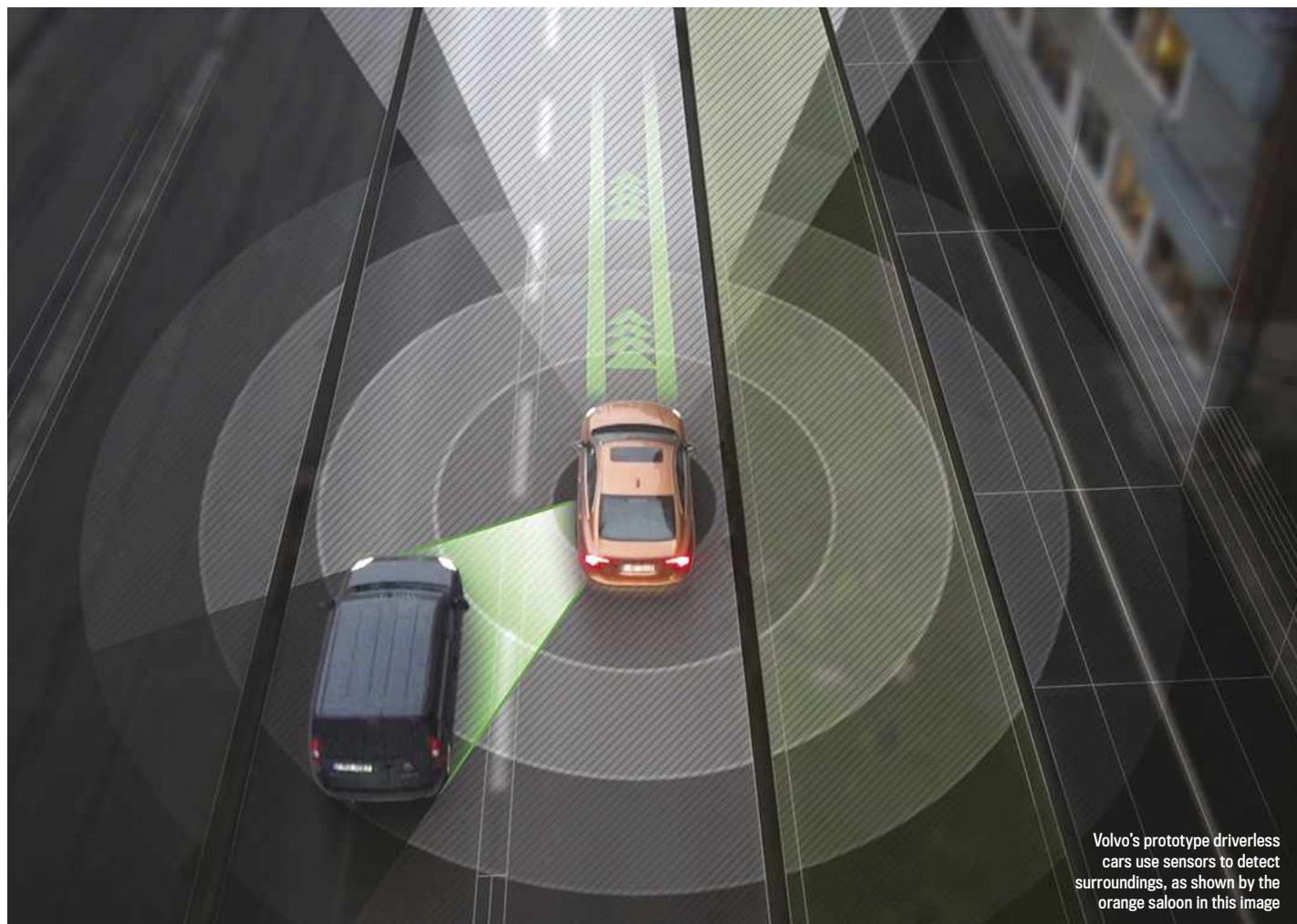
Erik Coelingh is keen for people to take over the driving when they want to

Reduced road deaths won’t be the only benefit of driverless cars, though. From improving traffic flow and reducing repair bills to cutting pollution and boosting economic productivity, driverless cars offer many benefits to the nation that cracks them first. The issue is whether the biggest challenges are technical or legal.

HOLD YOUR HORSES

Before you can bundle the kids off to school in your driverless Ford or Vauxhall, it remains to be seen exactly how autonomous the first generation of driverless cars will really be. Most researchers and robotics academics will be quick to point out that the term ‘driverless car’ actually describes quite a broad technological church.

Erik Coelingh is the technical lead at Volvo’s driverless car programme,



Volvo’s prototype driverless cars use sensors to detect surroundings, as shown by the orange saloon in this image

➔ which will see 100 self-driving cars with radar and laser transceivers take to 48km (30 miles) of roads in and around Gothenburg. “Self-driving cars mean different things to different people. There is Google’s approach of small pods to get around urban traffic. However, we want to offer a model which lets you select when you want to drive and when you want the car to take over,” Coelingh explains.

“Many of our models feature cruise control, emergency braking, lane departure warning systems and self-drive functions, so arguably these already offer an element of autonomy. But they don’t work in every situation. What we’re doing now is adding multiple sensors together for increased robustness and redundancy,” he adds.

There are already signs that engineers are fine-tuning their creations. For example, Google announced late last year that it had reprogrammed its cars to behave more



Google's driverless car 'pod' prototype has no steering wheel or pedals

aggressively and to drive “the way the people drive”. This means they will now start to inch forward at junctions, and drive closer to the car in front on busy motorways (to prevent other cars cutting in). The idea is that autonomous cars have faster reaction times, so can safely drive assertively.

This fine-tuning came about because most driverless car technology, including Google’s sensor system, has mastered what Coelingh calls ‘the basic navigation challenge’. What’s comes next is handling obstacles, poor weather and risky scenarios.

ON THE ROAD

To enable driverless cars to manage complex situations, such as city traffic, roundabouts, poor weather and motorways, they require advanced sensors and complex problem-solving software. Leading the way is Lidar. This light detection and ranging system bounces lasers off reflective surfaces to ‘fix’ millions of points every second as a car travels along. This technology is already used in mapping, and when combined with traditional radar and camera technology, it can allow driverless cars to spot danger at junctions and navigate roundabouts.



In 2012, Google's self-driving Toyota Prius manoeuvred through Washington, DC

WHAT IF YOU HAVE A CRASH?

GOOGLE HOPES THAT its driverless cars will be on sale from as early as 2017. But even with the alterations to The Highway Code, the legal implications of taking them on the public roads are still unclear.

"Driverless cars are being introduced to make roads safer," says Jenny Maloney, a technology lawyer at multinational law firm Slater & Gordon. "But accidents will still happen and a big concern is that people injured in collisions caused by driverless cars will be left without a legal remedy." Her worry is that we don't know if road traffic insurers will pay compensation for injuries caused by software, rather than by a human driver.

"The real difficulty is that there are a range of possible reactions to dangers on the road," she adds. "We will no doubt see situations where driverless cars have reacted to sudden hazards

but, in that unique scenario, it wasn't the right response and an accident was caused. Whose fault is it then?"

Stephen Hamilton of UK law firm Mills & Reeve agrees. "What we are likely to see is a series of phases of testing," he says. "You don't test seatbelts by heading out onto the road and looking for a crash. Instead, with driverless cars, we will see more complex trials on public roads as the technology is proven. The final hurdle will be how the cars react in critical situations, such as potential accidents or extreme weather."

Another consideration that is already baffling lawyers (if not engineers) is what would happen if two driverless cars packed full of passengers detect that they are set to collide. Unless there is some connectivity between autonomous cars on the road, how would they decide which of them should take evasive action? The answer is far from clear.

Alongside this, many driverless cars also use high-definition cameras in a technique called 'computer vision'. This uses software to analyse 360-degree images captured by up to 12 cameras on the outside of the vehicle. This data can be used to warn of pedestrians, cyclists and road works, but as RobotCar UK's Prof Paul Newman admits, it's not quite up to scratch for spotting something as small as a plastic bag. The issue is not a hardware one: digital images, regardless of quality, are just a bunch of numbers organised in a matrix. Giving computers the ability to understand what these images represent is the key.

Driverless cars also make use of the global positioning system from satellites, as well as peer-to-peer communication with other vehicles. This gets engineers like Dr Curran excited, as there is the possibility of sharing weather, traffic and roadworks data.

Even when complex navigation issues are overcome, there are still obstacles. In November 2014, Hugh Boyes, head of cybersecurity at the Institute of Engineering and Technology, warned that there could be "chaos" if hackers took control of driverless cars, and that software security could be a "major issue" for manufacturers and insurers. The FBI has warned that driverless cars could be lethal weapons if hacked or in the wrong hands.

But as Stephen Hamilton, a lawyer with British firm Mills & Reeve who has consulted with the government on

"A pod-like vehicle without a steering wheel is still at least 15 years away"

Erik Coelingh at Volvo's driverless car programme discusses truly autonomous vehicles

driverless cars says, these issues are often just as true in traditional cars. "We shouldn't expect driverless cars not to crash or to be totally secure. Even a 30 or 50 per cent reduction in accidents would be a huge success, when you consider that 1.2 million die each year on the roads worldwide."

With firms like BMW and Land Rover saying driverless cars could end up on dealership forecourts within 10 to 15 years, it seems that even petrolheads like Chas Hallett, editor of *Autocar* magazine, are increasingly convinced. He says: "There are a lot of concerns over driverless cars. But there are real benefits for cities, communities and safety, which people will soon really welcome. As long as you can control when you want it, quite soon we'll regard driverless systems in the same way as we currently see cruise control."

As part of my job, I spend a lot of time testing the latest driver assistance gadgets,

such as lane departure warning and radar-guided cruise control. But during a recent visit to RobotCar UK in Oxford, I have to admit I was uneasy. The team, which is supported by Oxford University, Nissan and the UK Government, uses a Nissan Leaf electric car. The car still has a driver – it is more of an advanced driver-assistance programme than a truly driverless car – but moving along at 16km/h (10mph) it's bizarre to be focused on an iPad that controls the driving system instead of the steering wheels and pedals. Many drivers will be used to cruise control and parking-assistance features, but seeing the steering wheel move and the car turn by itself requires some mental adjustment.

In Sweden, Coelingh thinks we'll soon get used to our cars taking over on certain journeys, even if future roads aren't going to be dominated by fully autonomous pods. "The idea of a pod-like vehicle without a steering wheel is still at least 15 years away, and even then there might never be a demand for that," he says. "What we are designing – and what we and other manufacturers are racing to perfect – is a system where you can drive if you want to or enjoy it, but you can turn to a highly advanced autonomous system to take control when you don't feel like driving." ■

JAMIE MERRILL is *The Independent's* news reporter and in-house car reviewer





10 WAYS TO BEAT THE FLOODS

This time last year, the UK suffered widespread flooding. Here, **Tom Heap** investigates projects that could help us stay dry in the future...

THE EARTH'S weather, encouraged by climate change, seems to be becoming more unpredictable.

In some parts of the world, rains are getting heavier and storms are intensifying. A Royal Society report published in November 2014 stated bluntly: "Climate change will


drive wet regions to become wetter".

Urban populations are starting to swell, but this is hugely problematic as many of our big cities are built on large rivers or near the coast, which puts residents at risk when the tides start to rise.

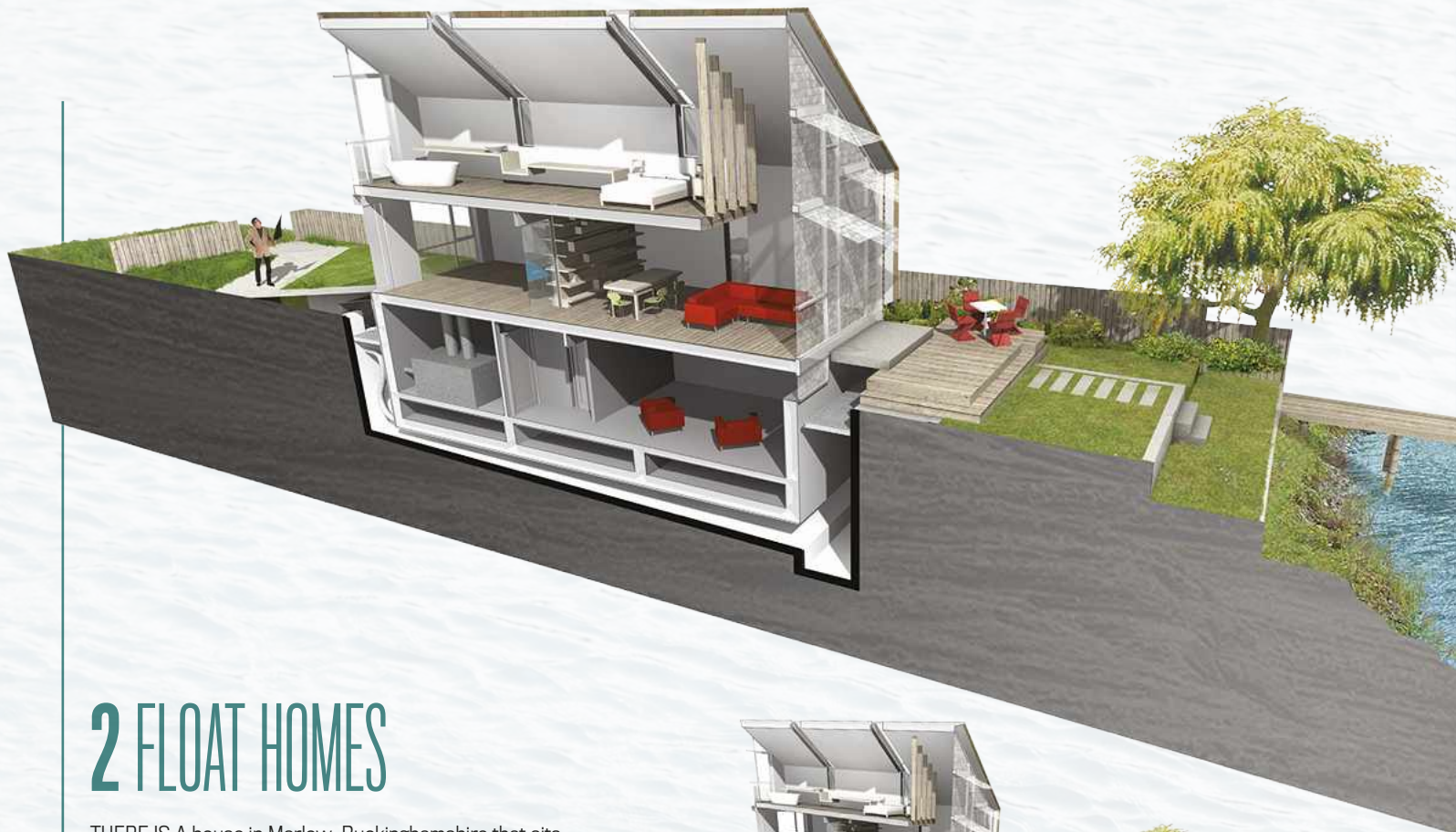
So what can we do to beat the floods? Read on for 10 innovative solutions.

1 TACTICAL RETREAT

HARD SEA DEFENCES, such as concrete, are rather out of fashion. The ocean often batters them into submission after a few years, or they just deflect the destructive energy elsewhere. In November 2013, the sea wall at Medmerry, West Sussex was scuttled in Europe's biggest coastal realignment. The Environment Agency built 7km of sea wall further inland, and the farmland between the barrier and the ocean became a salt marsh. This new wetland habitat is great for birds, but is also able to absorb the power of the sea and reduce the flood risk for hundreds of homes. It's too early for definitive proof of success, but the locals stayed dry in the storms of January 2014.

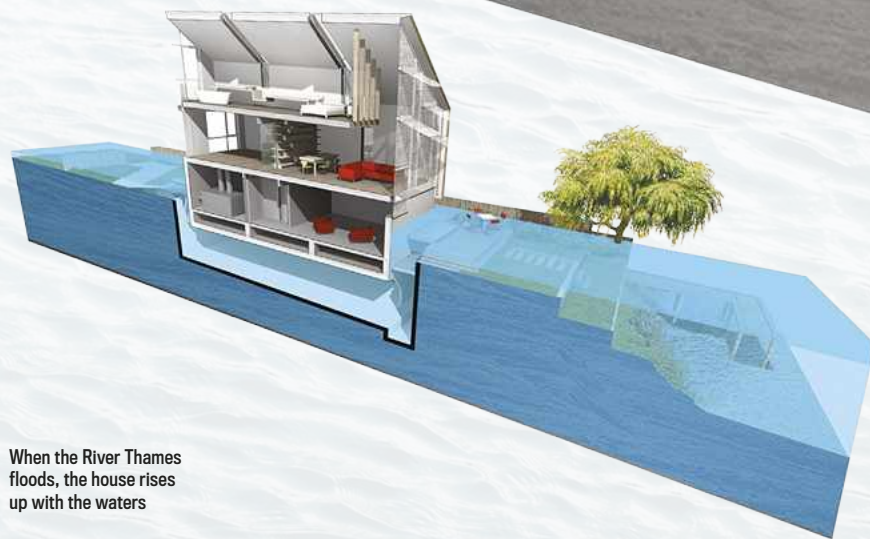


Medmerry is now protected from the sea by a new wetland habitat



2 FLOAT HOMES

THERE IS A house in Marlow, Buckinghamshire that sits by the River Thames. From their lounge, the occupants will be able to watch the weather with serenity. The rains may pour and the river may rise... but so will their house. Most of the time, the structure rests on the riverbank, surrounded by garden like any other home. While it looks like a modern house from the outside, the cunning part lies beneath the main building. Waterproof concrete wraps around the basement level, and this sits in a reinforced yet porous hole in the ground. When the floods come, the whole house floats up, guided by four vertical posts. The dwelling can rise by a whopping 2.5 metres. It is the first house of its kind in the UK and the owners hope to be installed by the start of 2015.



When the River Thames floods, the house rises up with the waters

PHOTO: BACA ARCHITECTS X2, ALAMY, CORBIS, GETTY



Worcester floodwaters in February 2014

3 BE WATER-RESISTANT

AS MANY AS five million homes are at risk of flooding in England. These houses won't be knocked down soon, so it makes sense to retro-fit the buildings rather than construct new ones. Houses can be fitted with floodproof doors to prevent water from seeping across the threshold. Ventilation bricks can be equipped with covers, or can even be replaced with ones that close up automatically as water approaches.

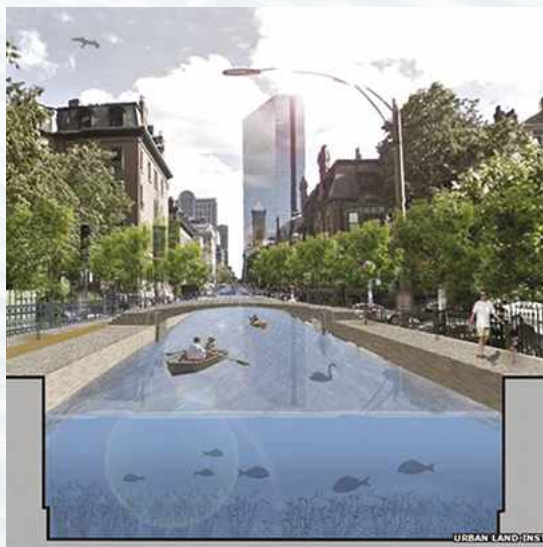
After 24 hours in a flood, water may start to ooze through the walls of houses. However, if the exterior is given a water-resistant nano coating, then this problem is prevented. Solid floors, magnesium oxide wallboard and waterproof paint can help keep repair costs down if floods manage to enter someone's home.

4 RECRUIT BEAVERS

BEAVERS ARE FAMOUS for building dams and are natural river basin engineers. Following serious floods in the UK during the winter of 2013-14, The Mammal Society recommended a widespread reintroduction. In Scotland, there is currently a trial release of beavers taking place in Knapdale, and the first batch of reports was released in November 2014. Valleys where beavers thrive are a patchwork of ponds and dams, creating a massive natural sponge that holds and slows the flow of rivers. In Pickering, Yorkshire, The Forestry Commission and other landowners are trying to replicate beavers' methods by creating a network of dams, bunds and wet woodlands. This should help prevent the impact of floods, without splashing out on expensive and unsustainable defences.



Dam built by beavers in Knapdale, Scotland



Concept of a canal network in Boston, Massachusetts

5 REPLACE THE ROADS

COULD BOSTON BECOME the Venice of New England? Planners, scratching their heads in the face of increased local rainfall, rising sea levels and low-lying districts, suggested replacing the roads of Back Bay with canals. This would create a network of channels, pumps and sluices linking to new wetlands, enabling the management of water rather than its exclusion.

A similar philosophy underpins plans for a development on Deal Ground in Norwich. The site is prone to flooding, so Baca Architects wants to put 40 per cent of the houses on stilts and the rest on raised land. Waterways between buildings will be dug unusually deep to accommodate excess water, and will help irrigate nearby wetlands. Baca Architects claims that the 670-home development will alleviate flooding pressure downstream.

6 REMOVE THE RAIN

JAKARTA FLOODS REGULARLY. In the last 20 years there have been four serious events – these have claimed hundreds of lives and cost millions of pounds in damage. The worst floods take place when high tide meets heavy rain, so the government's Weather Modification Technical Unit decided to make the rain fall elsewhere. They are using cloud seeding, which involves spraying particles into the clouds to encourage ice crystal formation and trigger rain. Planes have been scattering tonnes of salt above the ocean, therefore causing it to rain at sea rather than on land. While officials claim to have cut precipitation in Jakarta, many academics question this conclusion and want more proof. The authorities are undeterred and are requesting more aircraft for weather modification in 2015.



Workers in Jakarta loading salt, which will be transported to aircraft for cloud seeding

7 FARM ON THE WATER

TO SURVIVE WHEN the waters rise, we need food as well as shelter. In Bangladesh, where floods are a fact of life, floating gardens have been created. A raft of water hyacinth, which is a buoyant and persistent plant, is assembled and held together with bamboo. A layer of dung, soil and compost is applied, into which the crops are planted. Typically, one of these floating vegetable patches is about 1m x 8m, so it can be tended from a boat and towed to the marketplace. Bangladesh is also pioneering floating duck coops, allowing locals to sell eggs as well as veg.

Floating gardens allow locals to grow crops, even when their land is underwater

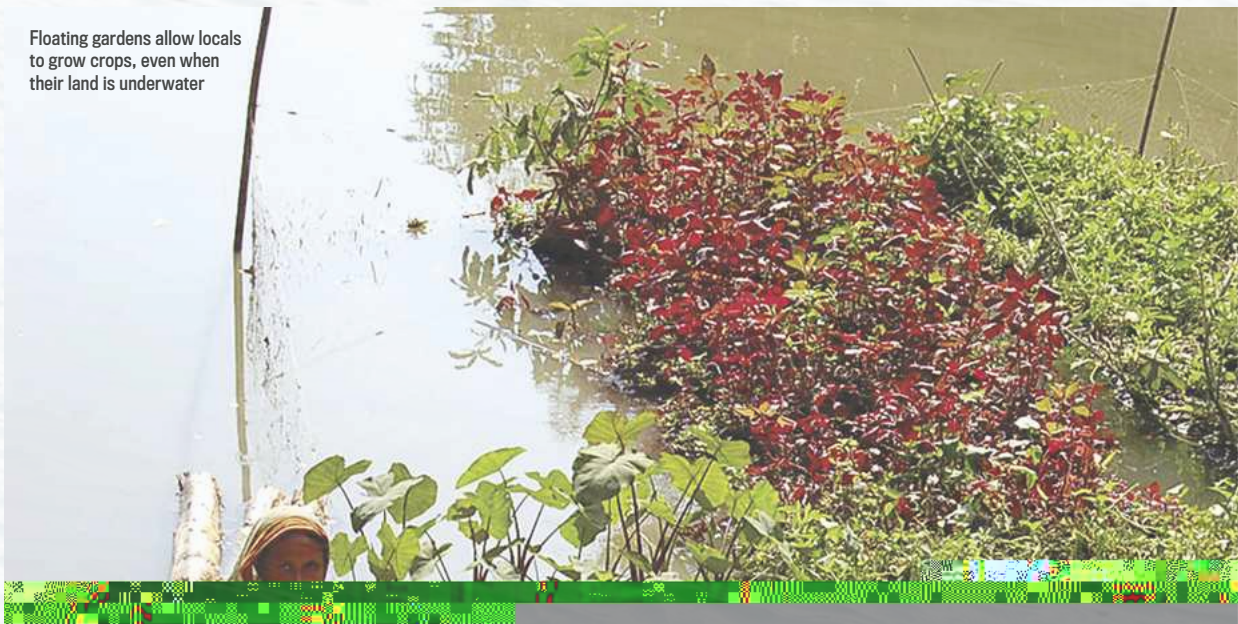


PHOTO: PRACTICAL ACTION.ORG, CORBIS, BIG U/REALBUILD BY DESIGN.ORG, US SUBMARINE STRUCTURES

8 LIVE UNDERWATER

FOR AROUND £6M you could live beneath the waves, just like the Bond villain Blofeld. The H2OME dwelling, which is built by US Submarines Inc, is an underwater lair that is accessible via a spiral staircase from your own private floating pier. The 464 square metre structure sits 10-18 metres below the surface – the shallow depth means that the living space doesn't need to be pressurised. As most of the light and life in the ocean is situated just beneath the waves, the H2OME will truly offer a room with a view.

As fewer than 100 underwater habitats have been built in the last 50 years, it could be argued that our survival rests on keeping our heads above water rather than slipping beneath the surface.



As Sebastian from *The Little Mermaid* would say: "Darling it's better, down where it's wetter, take it from me!"



The city of Jeddah after floods hit in January 2011

9 RELEASE THE DRONES

EARLY WARNING SYSTEMS can mean the difference between life and death. But predicting the path and volume of water, especially flash floods, is very difficult. Even Saudi Arabia, which is an arid region, has seen 100 people killed by flash floods in the last five years. Scientists from Jeddah have been working on a drone system to give up to two hours notice before a flood hits. Once a flood is

deemed likely, 10 minicopters take to the air and drop wireless sensors across the region. If the sensors land in floodwater, the drones track their progress. The data gleaned creates a map of the flood's movement, therefore allowing authorities to deliver accurate evacuation alerts. The sensors only have to ping their location over a short range, so their design can be simple, cheap and disposable.

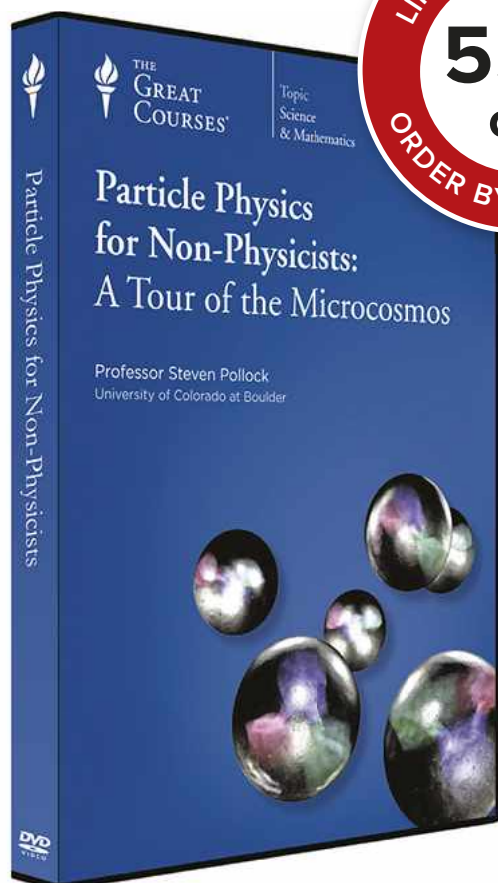


The Big U would hug Manhattan's edge and feature waterfront parks

10 BIG WALLS

WHEN TOWERING SKYSCRAPERS are being lapped by rising oceans, there really is only one survival strategy: a sea wall. Hurricane Sandy struck New York in 2012, killing 53 people and causing almost \$20bn (£13bn) of damage. To prevent destruction on this scale again, a wall is going up around the Big Apple. The 'Big U' is being masterminded by Danish and Dutch engineers, and will wrap around 16km of lower Manhattan's coast at a cost of \$335m (£213m). To maintain the city's identity, the structure will be hidden within landscaped areas. ■

TOM HEAP is a regular television presenter on *BBC Countryfile* and *Panorama*



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10. Fields & Forces
11. "Three Quarks for Muster Mark"
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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN
Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service



LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN



Q SIMON LENTON, LEEDS

What is the wettest place in the world?

IT'S MAWSYNRAM in the northeast of India. The village sits in the Khasi Hills, which funnel the warm, moist air from the Bay of Bengal and force it to rise, dropping almost 12 metres of rainfall every year! Despite this, the village can still suffer from drought during the dry season, which runs from December to February. **LV**

The village is 1,400m above sea level. Thirty years ago, it had no paved roads or electricity

PHOTO: REX

In Numbers

5,793

is the distance in kilometres that the Orion test flight flew above the Earth's surface in December 2014

Q TIM FARLEY, BRISTOL

Could phages be used as an alternative to antibiotics?

A THEY ALREADY ARE, to some extent. Bacteriophages, or 'phages' for short, are viruses that target specific bacteria. The virus penetrates the bacterial cell membrane and hijacks its DNA machinery to produce more copies of itself. This eventually ruptures the bacterium, killing it and releasing more phages.

Phage therapy is actually at least 90 years old. It was used extensively in Russia during the Cold War, when access to western antibiotics was limited. Phages get around the problem of bacteria evolving resistance because they are constantly evolving themselves. The downside is that you need a very specific phage to target every different bacterial strain. In practice, this means administering a cocktail of different phages and updating the recipe every few months. Phage therapy is currently only approved in Russia and Georgia, but interest in other countries is currently soaring. **LV**



A bacteriophage (orange) injecting its DNA into an *Escherichia coli* bacterium (blue)

Scratching is a behaviour that's common to all vertebrates



Q LUKE SPALDING, BIRMINGHAM

Why does it feel good to scratch?

A STUDIES USING FUNCTIONAL magnetic resonance imaging (fMRI) have shown that scratching causes patterns of brain activity that are associated with pleasure and reward. This effect is strongest when you do the scratching yourself and when you are actually scratching an itch, rather than just an arbitrary patch of skin. But contrary to what you might expect, or

might have read elsewhere, there's no clear evidence that this pleasure comes from a release of endorphins – it happens purely in your brain and spine.

This mechanism may have evolved to encourage us to dislodge skin parasites. All the evidence suggests that it's a very ancient response, because all vertebrates scratch themselves – even fish! **LV**

Q SUE ASHCROFT, ESHER

Do video games cause aggression?

Any link between gaming and real-world aggression remains highly contentious

A WE DON'T KNOW for sure, even though the question is important for education and parenting. Many studies show that kids who regularly play violent games show more savage behaviour, but this is only a correlation and not a cause. It could be that aggressive children prefer violent games, not that the games caused their aggression.

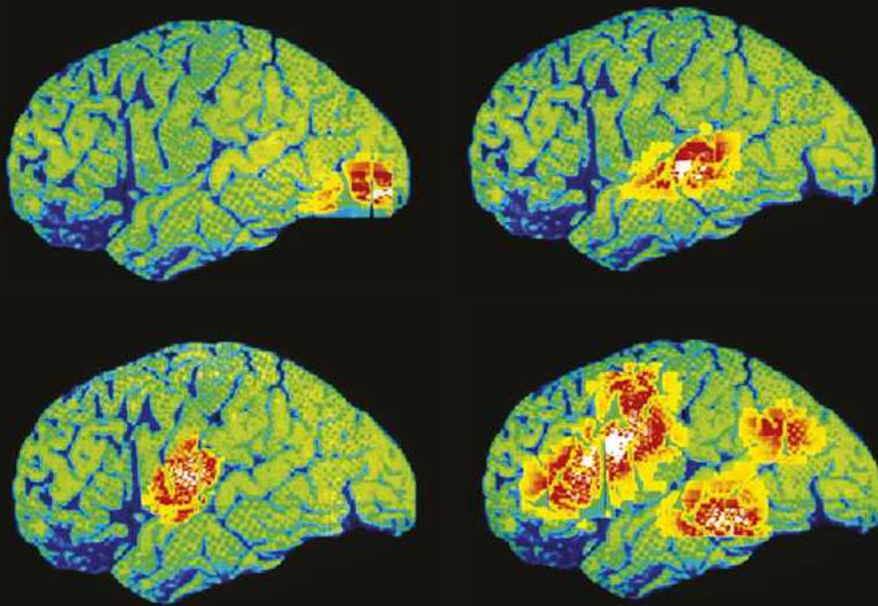
In some studies, the victor of a video game has been given the opportunity to punish their opponent by blasting them with noise, for example. It has been found that winners of violent games are

more likely to punish their opponent than winners of non-violent games. Violent games with a positive goal, such as saving others from virtual zombies, seem to have less negative impact.

Other research shows that losing the game or finding the controls frustrating is what leads to violence, not the content of the actual game itself.

We might note that US sales of violent video games have steadily increased since the mid 1990s, while violent crime has declined – especially among juveniles. **SB**

QUESTION OF THE MONTH

WINNER!Rob Myles wins
a copy of *100 Things
You Will Never Find*
by Daniel Smith
(Quercus, £15)

Clockwise from top left: brain areas active when seeing, hearing, thinking and speaking

Q ROB MYLES, LEICESTER

Does a brain with a higher IQ burn more calories?

A BROADLY SPEAKING, YES. Areas of the brain that are more active receive greater blood flow and take up more glucose. The increased blood flow is actually what allows fMRI scanners to detect brain activity. You might think that a less intelligent person would need to spend more calories on thinking harder about a given problem, but a 1995 study at the University of California, Irvine, found the opposite. When a mental problem seems easy for you, it is because you have more neurones that can work towards solving the problem. Your total energy expenditure is higher, but your subjective sense of the effort required is lower.

However, this research only looked at the short-term energy use while test

subjects were focusing on the problem. You can't generalise this to conclude that a higher IQ brain uses more calories over the course of an ordinary day. And in any case, the number of extra calories burned during thinking is very small compared to the base energy requirements of the brain when it isn't doing anything. Your brain uses about 300 calories a day just to maintain its own tissues. Concentrating on hard problems only increases this by 20 to 50 calories per day. That's about the same as you'd burn walking for four minutes.

So unless you're doing sudoku puzzles on a treadmill, mental activity will actually reduce your overall calories burnt, simply by taking time away from more physical activities. **LV**

Q SHELLY LLOYD, CANADA

Can germs survive on a bar of soap?



A bar of soap after washing out Frankie Boyle's mouth

A YES. WHEN YOU wash your hands, you transfer a thin film of bacteria, skin flakes and oils to the bar of soap. A 2006 study of 32 dental clinics found bacteria growing on the soap in all of them – after all, standard soap doesn't kill bacteria, it just dislodges them. A 1988 study found that washing your hands with a dirty bar of soap doesn't transfer any of the germs onto your hands – but then the study was conducted by a US soap manufacturer. **LV**

Q MICHAEL ALBIN, BLACKBURN

Is it best to charge your mobile battery from empty or half-full?

A NICKEL-BASED BATTERIES were blighted by the 'memory effect', and would lose capacity unless regularly discharged completely. Most phones nowadays have lithium batteries, and these do not suffer from the memory effect. In fact, it is good for them if you top the batteries up rather than deplete them completely. Therefore, it's best to charge your phone from half-full. **GM**



Don't wait for your phone to 'die' before charging it up

TOP TEN

BIGGEST CLOCK FACES

(BY DIAMETER)



1. Abraj Al Bait Towers Clock

Diameter: 43m
Location: Mecca, Saudi Arabia



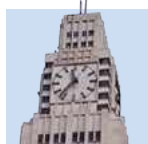
2. Istanbul Cevahir Clock

Diameter: 36m
Location: Istanbul, Turkey



3. The Floral Clock

Diameter: 24.2m
Location: Surat, India



4. Central do Brasil Clock

Diameter: 20m
Location: Rio de Janeiro, Brazil



5. Duquesne Brewing Company Clock

Diameter: 18m
Location: Pittsburgh, Pennsylvania, US



6. Colgate Clock (New Jersey)

Diameter: 15.2m
Location: Jersey City, New Jersey, US



7. Flower Clock

Diameter: 15m
Location: Tehran, Iran



8. Grozny-City Towers Façade Clock

Diameter: 13.6m
Location: Grozny City, Russia



9. Allen-Bradley Clock

Diameter: 12.6m
Location: Milwaukee, Wisconsin, US



10. Colgate Clock (Indiana)

Diameter: 12.2m
Location: Clarksville, Indiana, US

Q MILO SAINSBURY, CARDIFF

Can lightning strike upwards?



An upward discharge of lightning from a TV tower in Rapid City, South Dakota

A YES – AND SCIENTISTS at ZT Research in South Dakota have recently caught the phenomenon on camera. The footage revealed that a conventional lightning bolt can trigger a

change in the electric field in the atmosphere. Any tall building in the area is then liable to act like a lightning conductor in reverse, sending a bolt back into the clouds. **RM**

Q PETER FRASER, LONDON

How do we know when something is wet?

A OUR SKIN CONTAINS lots of nerve endings that respond to different stimuli. There are receptors for touch, vibration, heat, cold and pain – but not for wetness. Water is such a ubiquitous component of all living cells that it would be difficult for a nerve cell to avoid firing constantly in response to its own composition.

Instead, wetness seems to be a property that our nervous system learns to recognise, based on a mixture of cold, pressure and texture. A 2014 study at Loughborough University found that hairy skin is more sensitive to wetness than smooth skin, which may be because hairy skin has more temperature sensitive nerve endings. When you are born, you don't feel wet or dry, you just feel cold or warm. Over time we learn that the feeling of cold cloth sticking to our skin means that we've sat on a wet park bench. **LV**



In this situation, it's good to sing

Q TERRY FAIRHALL, CHESSINGTON

Is our sense of self an illusion?

A IF AN ILLUSION is something that deceives us, yes. Most of us feel we're more than just a body with a brain: we are someone who lives inside our body and controls it. Yet this cannot be true. The brain is a massively parallel system with no central place where a self could receive information or issue commands. Different regions make decisions, inhibit impulses, organise movements and control emotions, and these all operate at once without a central controller, some of them so quickly that we become aware of what's been decided only after the action is completed. Yet we still say 'I decided to do this' or 'I wanted to do that'. Our sense of a unitary 'self' that has consciousness and free will may or may not be useful – but it is certainly an illusion. **SB**



We can recognise ourselves in a mirror, but our sense of 'self' is not real

WHAT IS THIS?



KNOW THE ANSWER?

Submit your guess now at sciencefocus.com/qanda/what

LAST MONTH'S PICTURE

Stephen Aitchison correctly identified this picture of Martian sand dunes

Q MIKE REES, CUMBRIA

Why do different countries use different mains voltages?

A THE BIGGEST DISPARITY is between the USA on 110V and most of the rest of the world on 230V. America's lower voltage goes all the way back to Thomas Edison, who introduced direct current (DC) mains electricity at 110V. Edison's rival Nikola Tesla showed that long power lines transmitted alternating current (AC) more efficiently than DC. His AC approach won out, but he stuck with Edison's 110V. It's been that way in the US, Canada and parts of the Caribbean ever since. But by the time electrification spread to Europe early in the 20th Century, lamps had filaments that could give out more light and handle greater power loads. So the Berliner Elektrizitätswerke company in Germany established 230V as the standard. **GM**

Forget a plug adaptor and you'll be holidaying with a hairy face and no phone





Pipe dream? Global Thermostat's air capturing technology

Q DAVID WILLIAMS, LYTHAM ST ANNES

Could direct air capture prevent climate change?

A DIRECT AIR CAPTURE (DAC) is an appealing way to tackle climate change: just pass ambient air over chemicals that absorb the CO₂ driving global warming, and then use or store the CO₂. DAC differs from the better-known carbon capture and storage (CCS) in that it can be done anywhere, not just at big sources of CO₂ such as power stations. It's more effective than natural CO₂ 'scrubbing' using trees and plants, and can be performed where the CO₂ is most easily stored or re-used.

Like CCS, however, DAC faces the problem of ensuring the CO₂ never escapes. Unlike CCS at power stations, DAC must be effective at removing the far more dilute CO₂ in ambient air. This demands special equipment and chemicals, plus renewable energy sources producing zero CO₂. That has led to grave doubts about the economic viability of DAC. For now, it remains an intriguing but impractical remedy for global warming. **RM**

In Numbers

-18°C

is the lowest temperature to which Alaskan wood frogs have been chilled (with 100 per cent survival rates). Their cells contain glucose, which acts like an antifreeze

Q ZAC GLADMAN, BUCKINGHAMSHIRE

Why do we go red in the face when embarrassed?

A HUMANS SEEM TO be the only animals to show embarrassment, and Charles Darwin called blushing "the most peculiar and most human of all expressions". Blushing makes it harder to lie, which seems like a disadvantage. However, a 2009 study by Dutch psychologists found that we are more likely to give people a second chance if they blush when they betray us. The ability to blush acts as a signal that you are sensitive to the social rule you have just broken. Psychopaths, on the other hand, do not blush at all. **LV**



Relax: this woman is officially not a psychopath

Q JOHN BLANNING, BRISTOL

Why aren't our Solar System's planets and moons made from the same material?



Planets formed as more and more material clumped together

A THE SOLAR SYSTEM formed from the collapse of a molecular cloud consisting mostly of hydrogen, but also containing heavier elements. As the cloud collapsed, its central region began to heat up until eventually the hot 'proto-Sun' was formed. The planets formed by the accretion of material from within this cloud. Due to their high boiling points, only metals and silicates could exist in solid form in the hot, inner regions of the early Solar System. More volatile elements either remained

gaseous or were blown away by the Sun's energy. Since this heavy material existed mainly in the inner regions of the Solar System, the planets that formed there are small and rocky. In the cold outer reaches of the Solar System, compounds with low melting points could remain in solid form. These ices were also much more abundant than the heavier elements. The outer planets were therefore able to grow much larger, and held onto large atmospheres of hydrogen and helium gas. **AG**



Q Where could the next natural disaster strike?

Around the world, catastrophic events are waiting to happen. **Bill McGuire** reveals where nature is set to wreak havoc next



A CALIFORNIA, USA

MAMMOTH MOUNTAIN



Mammoth Mountain is a leading destination for skiers, but it hides a dark secret within

BEST KNOWN AS a ski resort, Mammoth Mountain has a darker side to its character – it is an active volcano. It is one of more than 30 cinder cones and lava domes that dot the western rim of the Long Valley Caldera supervolcano. Mammoth has not disgorged any magma for close to 60,000 years, and it's 700 years since steam blasts shook the mountain. Still, the volcano has shown signs of unrest in recent decades, with earthquakes, swelling of the ground surface and tree dieback due to sulphurous gases seeping from the soil. This caused real concern in the late 1980s and 90s. A swarm registering up to 300 quakes a day was detected near the volcano in late September 2014, but things had calmed down by early October, and monitoring scientists say there is no sign of an imminent eruption.



A ANYWHERE

EARTH



Asteroid 2014 UR116 would do some serious damage were it ever to collide with our planet

A RUSSIAN ROBOT telescope called MASTER has spotted a new asteroid that could threaten our world. The space rock 2014 UR116 is 370m across and in an unstable orbit around the Sun that could ultimately place planet Earth in its sights. Currently, the asteroid's orbit does not bring it within 4.5 million kilometres of our world, but regular encounters with the gravitational fields of Mars and Venus during its circuits around the Sun are likely to modify its trajectory. All that observing scientists currently say is that it will not strike Earth in the next six years. If it does eventually end its life through collision with our planet, the blast will be around 1,000 times greater than that announcing the spectacular arrival of the Chelyabinsk meteorite over Siberia in 2013. It would be insufficient to end our civilisation, but big enough to obliterate a city should one get in its way.



A HONSHU ISLAND, JAPAN

TOKYO



If another major earthquake comes in the wake of Tohoku in 2011, the results will be disastrous

EARTHQUAKES DON'T COME much more devastating than the expected Tokyo quake. The greater Tokyo area is home to 35 million people, who await with dread the quake that must come soon. Since the huge 2011 Tohoku earthquake and tsunami, seismic activity in the region has increased tenfold, and a recent study says the chance of a mag. 7+ quake striking by 2016 could be as high as 70 per cent. This could result in the destruction of over 600,000 buildings and the loss of up to 23,000 lives, due to either building collapse or post-quake firestorms. With the cost projected to be close to one trillion US dollars, the impact on Japan's economy would be catastrophic.

BILL MCGUIRE is Emeritus Professor of Geophysical & Climate Hazards at University College London and author of *Waking The Giant*



Brain training games are fun, but chess is better for your mind

Q SARAH ALDER, PENZANCE

Can 'brain games' really slow memory decline?

A PROBABLY NOT, DESPITE the claims made for them. Some scientists accuse the multi-billion dollar industry of preying on people's fears of memory loss. Playing any brain game increases scores on that and similar games, but this does not necessarily mean a general improvement in memory. Games like

chess, bridge and Scrabble that demand strategic thinking as well as memory may be more helpful. Playing 'brain games' may even be detrimental to elderly people if it keeps them away from getting out, seeing friends and taking exercise. These are the activities that really keep our brains functioning well into old age. **SB**

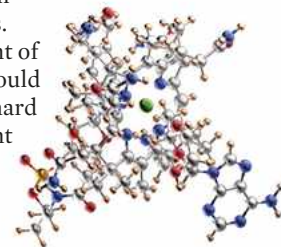
Q DENISE CARLSSON, LONDON

Are our bodies naturally herbivorous?

A NO. THERE ARE many reasons to be vegetarian, but your evolutionary heritage isn't one of them. We have no fermenting chamber in our intestines to digest plant cellulose, and our metabolism has several adaptations that suggest we evolved from animals that ate meat: for example, our intestines have receptors to absorb heme iron, which is only found in meat. We also can't make our own vitamin B12, and we synthesize taurine and vitamin A very slowly. These nutrients are much easier to get from meat than plants.

Before the advent of agriculture, it would have been very hard to get all the right nutrients from plants alone. **SB**

Grazing alone would not have given us enough vitamin B12



Q DENISE CARLSSON, LONDON

Can you avoid setting off motion-sensitive lights by moving slowly?

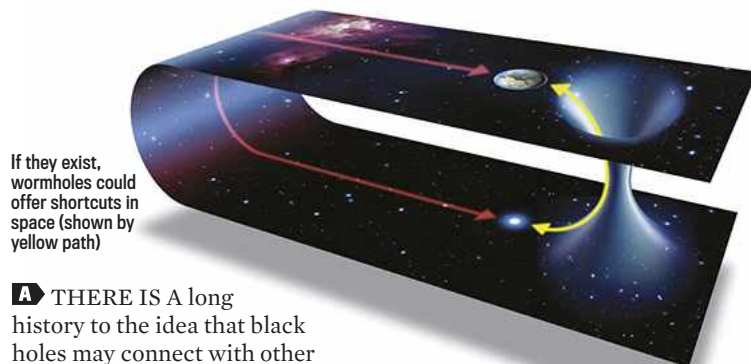
A MOST MOTION-SENSITIVE security lights detect heat from your body and are triggered if the infrared radiation received at the sensor changes sufficiently quickly. The lamps ignore gradual variations – if they didn't, the temperature changes of the surroundings between day and night would set them off. It depends on the lamp, but my own experiments reveal that you have to move slower than 0.1 metres per second, or 0.4km/h, to avoid being rumbled. **GM**



Motion-sensing lights can be 'tricked' if you move slowly enough

Q STUART LAWS, BY EMAIL

Could black holes be portals to other universes?



If they exist, wormholes could offer shortcuts in space (shown by yellow path)

A THERE IS A long history to the idea that black holes may connect with other regions of the Universe, or other universes entirely, but this is purely speculation. Some physicists have attempted to combine quantum mechanics with the General Theory of Relativity and concluded that black holes may not contain a 'singularity', the point at which density becomes infinite. This would open up the possibility that black holes are shortcuts

to other universes. Actual tunnels through space-time, called 'wormholes', may be a better bet for traversing between universes. But although they're predicted by Einstein's theories, no wormholes have yet been discovered, and there are doubts that they could occur naturally at all. **AG**

Q ANDREA CAPEL, LOUGHBOROUGH

Are 'statistically significant' results really significant?

A OFTEN USED TO describe a new research finding, statistical significance is one of the most misunderstood scientific terms – even by scientists themselves.

To gauge whether the result of some experiment is 'significant' or not, formulae are used to work out the chances of getting at least as impressive a result if fluke was the true cause. If these are less than 1 in 20, then the result is deemed statistically significant. But – contrary to what many scientists think – this doesn't mean the chances of the result being a one-off are also 1 in 20. As the calculation was made assuming fluke to be responsible, it can't give the chances of that assumption being right. In order to work that out, the inherent plausibility of the finding is taken into account. Phew! When all these calculations have been made, many 'statistically significant' but implausible findings end up showing a high risk of being flukes.

Statisticians have issued warnings about the dangers of misunderstanding statistical significance for decades, to little or no avail. Some now suspect this misunderstanding lies behind the current 'replication crisis' in science, where many research findings fail to be confirmed by follow-up studies. **RM**



Science isn't all about playing with microscopes and making explosions – there are tough statistics to deal with

Q ALEX ROUND, LONDON

Why do snakes have slits for pupils?

A VERTICAL PUPILS ARE an adaptation for ambush hunting. A 2010 study at Sydney University found that of 127 Australian snake species, the ones that ambushed their prey by night had vertical pupils, while those that actively chased down prey in the day had round pupils. The constriction of round pupils helps distant prey stay in focus, but it also lets in less light. Vertical pupils improve vision across a wider range of light levels, and enable the animal to detect horizontal movement more effectively.



The vertical pupils of a reticulated python tell us that it ambushes prey

It's also possible that vertical pupils are more camouflaged, since they break up the round outline of the eye. **LV**

Q ROB MYLES, LEICESTER

What is emotional intelligence (EI)?

A EMOTIONAL INTELLIGENCE (EI) is the ability to recognise emotions in yourself and others, and to apply that understanding in behaviour and relationships. People with high EI have more empathy and self-awareness, and are better able to put themselves in others' shoes. Women usually score higher than men, especially on empathy. The concept arose when traditional IQ tests were criticised for measuring only a narrow range of intellectual skills, and attempts were made to replace them with multiple intelligences such as musical, moral and bodily intelligence.

There is some evidence that bullies tend to be low on EI, while religious believers score higher. Many other claims have been made, such as that EI can predict leadership skills and teamwork. Yet all these have been challenged on the grounds that any effect disappears when IQ and personality are accounted for. Therefore, the idea that emotional intelligence is separate from general intelligence remains controversial. **SB**



It's not all about IQ. Emotional intelligence is important too

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THERAPY ON TAP

Fewer murders, reduced suicide rates and a lower risk of Alzheimer's... could adding lithium to our water bring all these benefits? **Jo Carlowe** investigates

IMAGINE A FUTURE in which our health, behaviour and mood are determined by chemicals in our water. It might sound like something out of *Brave New World*, but the idea may not be so far off: in Scotland, scientists are investigating whether lithium in the water supply might have an 'anti-suicide effect'.

The research stems from the fact that lithium is a known mood stabiliser. Indeed, it is used in psychiatry to treat bipolar disorder. Since its therapeutic properties were discovered in 1949, it's been credited with halving the suicide risk in patients with mental health problems. But the argument now is that all of us might benefit from imbibing more lithium.

While the workings of lithium are not fully understood, most experts believe it strengthens nerve cell connections in the areas of the brain associated with mood regulation and behaviour. As a result, it reduces the symptoms of mania, impulsive behaviour and depression. Some scientists go further, and claim it also heals nerve

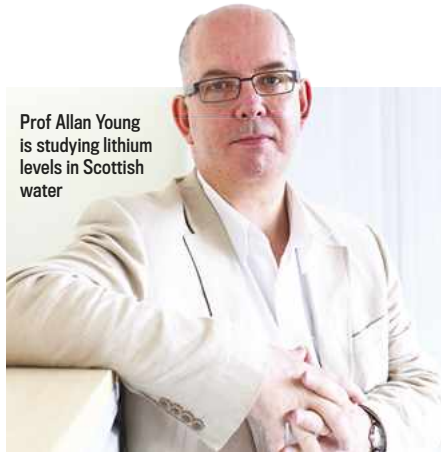


damage and protects against the onset of dementia. So now experts are trying to test whether daily exposure to small amounts of environmental lithium might be of health benefit not just to those already suffering from depression, but to the population in general. Most of us are already exposed to some lithium, as it occurs naturally in tap water. But even in areas with high environmental levels this only translates to around 2mg a day, while therapeutic doses typically start at 300mg daily.

In Scotland, Dr Daniel Smith, Reader of Mental Health at the University of Glasgow, is checking lithium levels by postcode, as listed by Scottish Water, and comparing them to data on suicide attempts by area, as listed in the Scottish Health Survey. It's anticipated that suicide rates will be lower in the areas where the lithium content in the drinking water is highest, and vice versa. If this proves to be the case, some might argue that this trace element should be actively added to tap water to help keep the nation stable.

But the idea of governments doctoring the water remains controversial. Indeed one scientist involved in the Scottish

Prof Allan Young is studying lithium levels in Scottish water



Lithium in a water sample from a salt flat in Bolivia

“Most of us are already exposed to some lithium, as it occurs naturally in tap water”

study, Professor Allan Young, who is director of the Centre for Affective Disorders at the Institute of Psychiatry in London, has received death threats since studying the impact of environmental lithium on our well-being. This is despite the fact that there is nothing new about adding chemicals to drinking water.

Water fluoridation to prevent tooth decay dates back to the 1940s. Today the majority of US citizens drink water with added fluoride, but in the UK only 10 per cent of us receive fluoridated water. Public Health England recently published a report

Pitkeathly Wells in Scotland was once a popular spa, famed for its lithia waters





The soft drink 7-Up
used to contain lithium



Adding fluoride to the
water supply, 1965



Fluoridated water can
help prevent tooth decay

showing that 28 per cent fewer five-year-olds and 21 per cent fewer 12-year-olds have tooth decay in these areas; there were also fewer cases of kidney stones and bladder cancer.

SPAS AND SOFT DRINKS

The notion that lithium in water might be healing has an even longer provenance than fluoride. Between 1785 and 1949, the lithium-rich waters of the Pitkeathly Wells spas in Perthshire, Scotland were popular for health and 'nervous problems', while the Lithia Springs in Georgia, USA were visited by Mark Twain and Theodore Roosevelt for their curative powers.

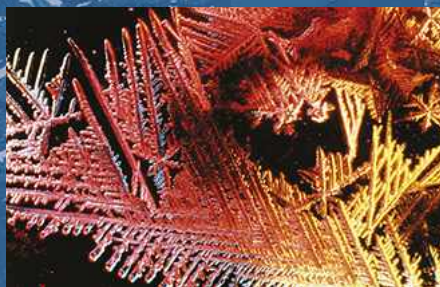
'Lithia water', high in lithium salts, was also added to many popular drinks, purportedly for its health benefits. One such drink was Bib-Label Lithiated Lemon-Lime Soda – an early name for 7-Up (lithium presumably providing 'the up', the '7' possibly representing its atomic mass). In the 1940s, changes in the regulation of the drinks industry, and concerns about lithium's toxicity, saw it removed from commercial beverages. Thereafter, following the discovery of its psychotropic benefits, it largely remained the preserve of the psychiatric community.

But in 1989 a scholarly paper was published in the USA called *Lithium In Drinking Water And The Incidences Of Crimes, Suicides, And Arrests Related To Drug Addiction*. The researchers examined the lithium level in the water of 27 counties in Texas. Incredibly, the area with the highest lithium level had nearly 40 per cent fewer suicides than the area with the lowest lithium level. Moreover, the counties with the highest levels of lithium in their water also had a statistically significant decrease in the incidence of homicides and rapes.

In 2009, an observational study from Japan also found that increased amounts of trace lithium in the water supply correlated with decreased suicide rates. Similar results were replicated in 2011 in Austria. The researchers took a nationwide sample of 6,460 lithium measurements and examined these for association with suicide rates across all 99 Austrian districts. The results again showed an inverse association – the greater the amount of lithium in a district's water, the fewer suicides. This remained significant even once the data had been adjusted for socioeconomic factors. The researchers concluded that as much as 4 to 15 per cent of the country's geographic

WHAT'S IN YOUR WATER?

Every time you fill up the kettle, you're loading up on more than just pure, unadulterated H₂O...



FLUORIDE

Fluoride occurs naturally, but some companies add extra at the request of health authorities. Only 10 per cent of people in Britain receive fluoridated water. Fluoridation protects against tooth decay, kidney stones and bladder cancer, but too much fluoride can cause tooth discolouration. In the UK, fluoride is limited to 1.5mg per litre.



CHLORINE

Water companies add less than 1mg per litre of chlorine (as recommended by the World Health Organization) to disinfect water. Swimming pools typically contain 3mg per litre. The Drinking Water Inspectorate (DWI) says chlorine is safe, but one study has linked high levels of dichlorophenol (a chlorine by-product) to food allergies.

variation in suicide rates could be attributed to varying levels of lithium in regional water supplies.

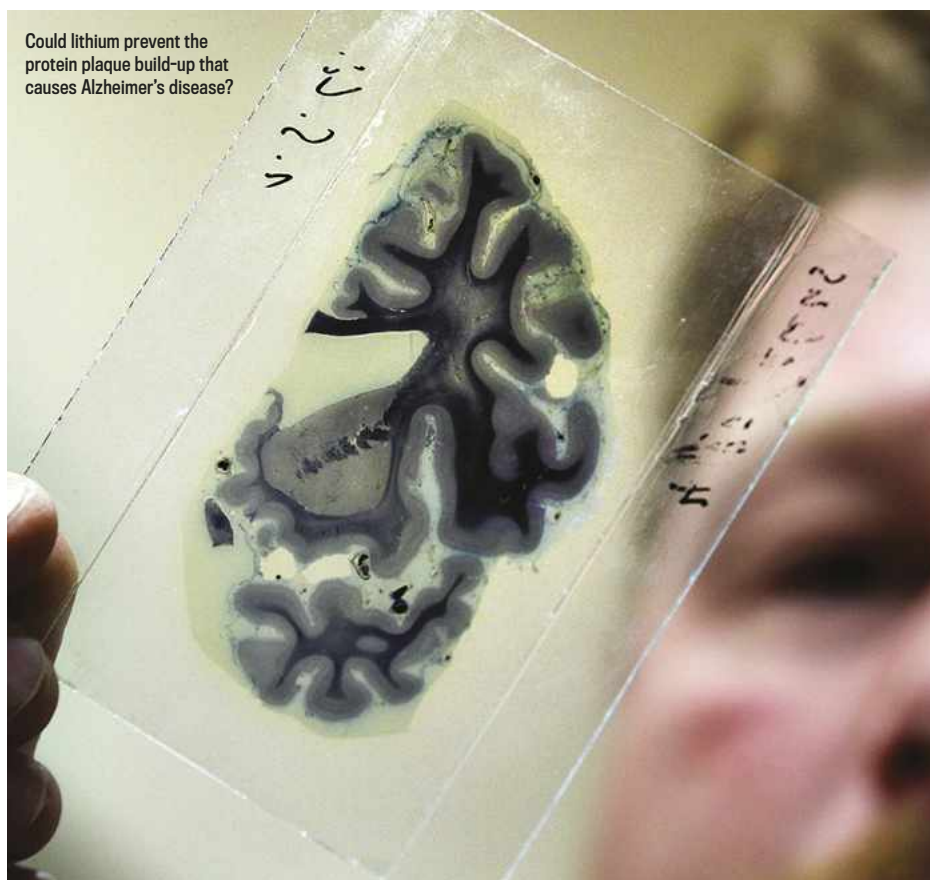
DEMENTIA PREVENTER?

Professor Young believes environmental lithium may also protect against dementia. He'd like to carry out studies in the Atacama desert in northern Chile, which has the world's highest levels of lithium in surface water – in some cases, levels are similar to a therapeutic dose. The local population have been exposed to this lithium-rich water their entire lives.

"Such exposures may have had significant structural, functional consequences not seen hitherto," says Professor Young. "If lithium is highly neuroprotective, long-term environmental exposure might reduce age-related degeneration and even prevent the development of disorders such as Alzheimer's disease."

A number of studies (both observational and studies on animals) already suggest that therapeutic levels of lithium may help prevent dementia. In a Danish study of bipolar patients, continued treatment with lithium was associated with a decreased rate of dementia. One of the hallmarks of Alzheimer's disease (AD) is the build-up of plaques of proteins in the brain (one called 'tau') that causes nerve cells to die. Lithium appears to protect against this.

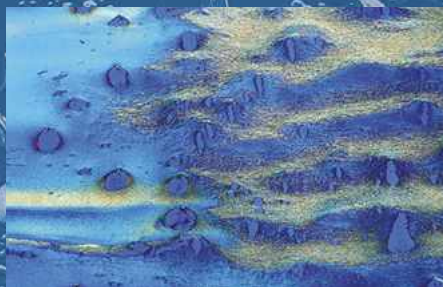
Simon Lovestone, professor of neuroscience at the University of Oxford, explains. "One of the enzymes that adds phosphates to tau is called glycogen synthase kinase 3 (GSK3). GSK3 is inhibited by lithium. Hence lithium should reduce tau phosphorylation, which should modify disease progression or perhaps



prevent AD. There is evidence from animal studies that it might."

However, he does not advocate the use of lithium for the general population. "Lithium has a very narrow therapeutic range and is highly toxic – at high levels it is associated with kidney failure," he says. "It is unimaginable to think it could be given in therapeutic range to anyone other than those with a reason to receive it."

But proponents of lithium say trials should be carried out to see if lithium at lower levels affords us protection against neural degeneration and unhappiness. Ideally, Professor Young would like to carry out research in Chile, where two valleys sit side-by-side, similar in everything but rates of lithium. He would look at rates not just of suicide but also of dementia, and carry out brain scans to see



PESTICIDES

Water companies use a combination of activated carbon and ozone to safeguard drinking water against pesticides. Recently, metaldehyde (used as slug poison) was found in one in eight rivers and reservoirs used for drinking water, according to an Environment Agency survey. The toxicity level, however, was viewed as 'very low'.



HEAVY METALS

Some trace elements such as magnesium are necessary for health, while others such as lead are not. Although not present in our public water supply, lead particles can build up in older pipes and intermittently in tap water. In high risk regions (soft water areas), water companies treat the supply with orthophosphate.



PHARMACEUTICALS AND ILLICIT DRUGS

Medicines and narcotics have been found in tap water, albeit at levels too low to be a health risk. The DWI recently discovered benzoylecgonine, a metabolised form of cocaine, in the UK. Traces of anti-epileptic drugs and anti-inflammatories such as ibuprofen have also been found.

"People don't get excited about lithium, because you can't patent it"

Professor Allan Young, director of the Centre for Affective Disorders at King's College London

if those exposed to high levels have more grey matter than those in low-dose areas. But this potential data goldmine remains untapped because funding has not been forthcoming. "People don't get excited about lithium, because you can't patent it and you can't make money out of it," says Professor Young.

EARLY DAYS

Perhaps the results of the Scottish study (due out in 2016) will change the scientific community's thinking on lithium. Maybe one day it will even be added to our drinking water, like fluoride in the USA. But as yet, even advocates of the idea remain doubtful. Dr Daniel Smith says there is currently not a single place in the world where lithium is added to the water supply for the benefit of public health. If his results reveal lithium to be protective against suicide, he says, more studies would still be needed before the results could have any impact on policy.

Professor Young, likewise, says there are "many scientific hurdles" to cross before such an idea could come to fruition. "But we should be doing the science," he says.

What water there is in the Atacama Desert has a very high lithium content

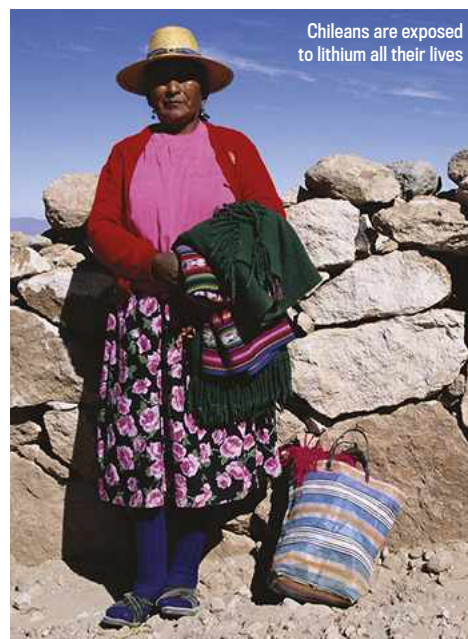


"There need to be more environmental studies about the impact of higher environmental lithium. If you couldn't put lithium in the drinking water you could give people much lower doses and study them over a prolonged period of time. The potential savings, if you reduced dementia, would be enormous. This is important for brain health, ageing and suicide. It is rather perplexing to me that there isn't a big research effort going on in this area."

The chances of lithia water becoming as commonplace as it was 50 years ago currently seem slim. But with the World Health Organization reporting 7.7 million new cases of dementia per year, and with one million people dying annually from suicide, the argument for at least doing the research is persuasive. ■

JO CARLOWE is a science journalist who writes for *The Times* and *The BMJ*, among others

Chileans are exposed to lithium all their lives



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THE FUTURE OF GADGETS

TECHHUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

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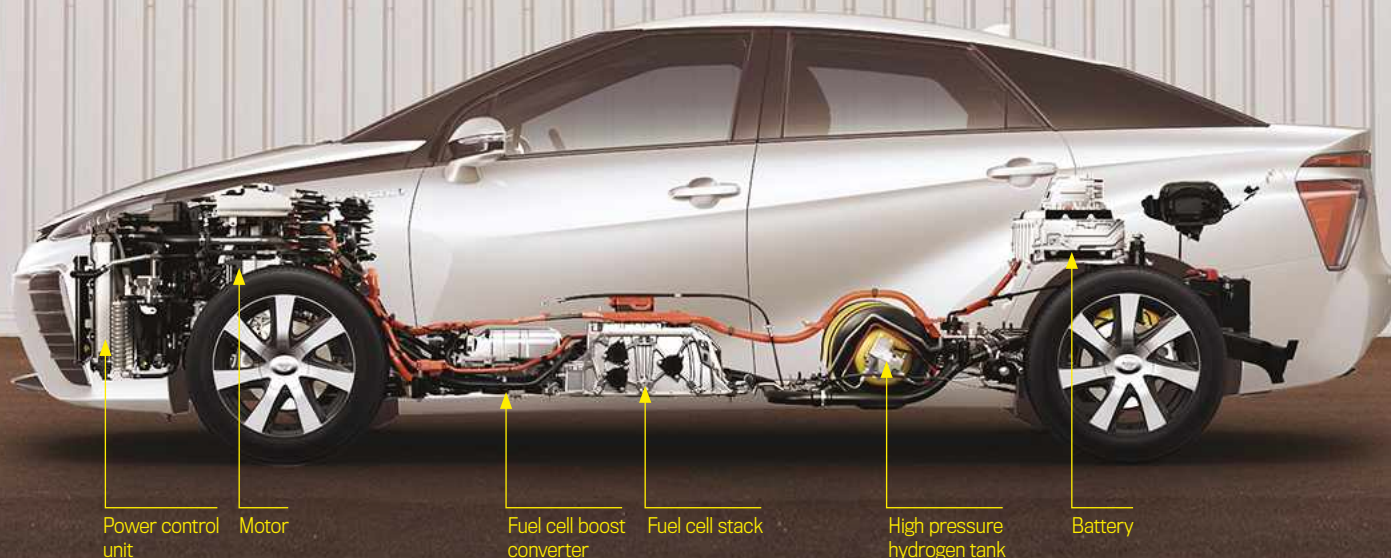
ON THE HORIZON

TOYOTA MIRAI

Hydrogen fuel cell car

Toyota.com

WORDS: **DANIEL BENNETT**



AT THE TURN of the millennium, Toyota introduced the world to the Prius. This hybrid car paired an electric motor with a combustion engine.

The Prius's sales figures proved that there was an alternative to petrol and diesel

cars, and motorists were hankering after something kinder to the planet.

Today, nearly every car manufacturer, from Porsche to Peugeot, now sells a hybrid model. So when Toyota described their latest car model as a "turning point" in history,

we thought that we ought to take a look.

This "turning point" is called the Mirai – which means future in Japanese – and it's powered by hydrogen fuel cells. More precisely, its fuels cells use hydrogen and oxygen to create electricity,

which then powers an electric motor hooked up to the wheels. The byproduct of the reaction is H_2O , so the only thing that will leave the car's exhaust will be steam. In terms of a successor to the traditional combustion engine it sounds like a no-brainer, ➔



The Toyota Mirai is powered by hydrogen and doesn't release any chemical nasties

➔ but there are still some hurdles in its way if it is to be a success.

Just like petrol, hydrogen is highly flammable. While the motoring industry has had the benefit of over 100 years of research and engineering to work out how to safely distribute, store, carry and use petrol, the hydrogen fuel cell industry is still in its infancy. But it's not starting from scratch as the idea of a hydrogen car has been around since the 1990s. Ever since then, Toyota claims that it has been testing the safest way to carry hydrogen around. The company's solution is a carbon fibre fuel tank that's incredibly solid and light. This tank is loaded with sensors that tell the car to isolate the hydrogen in an emergency. Given how strict the motoring industry is with safety standards, we're willing to bet that hydrogen cars will be no more dangerous than their petrol equivalents. But hydrogen fuelling stations are another problem altogether.

Before buying a car, early adopters will need to know whether the country's roads will be equipped with a fuel network that allows them to get around. Thankfully, that won't necessarily mean a huge number of stations. The Mirai will have a range of 300km, which is almost enough to get you from London to Manchester in

one trip. Compared to electric charging stations, only a relatively small number of hydrogen fuelling stations would be needed. In the US it looks like this won't be a problem. There are already plans to create a chain of stations linking the east and west coasts of America. The goal is to have 46 US stations open by the time the car goes on sale at the end of 2015.

In the UK, the number of predicted stations is a less optimistic six. But Toyota, buoyed by Tesla's success of installing a supercharger network across the US and UK, has few reservations that a hydrogen fuel network will pop up before long. Besides, Toyota is not alone because Honda and Hyundai are both launching hydrogen fuel cell cars as well.

Ultimately, the Mirai isn't about hydrogen fuel cells replacing the use of fossil fuels in cars (let's not forget the majority of hydrogen comes from fossil fuels at the moment) or batteries, for that matter. As Toyota states, the idea is to diversify the types of fuel we use, so that our way of life isn't dependent on one single fuel. Either way, there's little doubt that hydrogen cars are rolling into town.

DANIEL BENNETT is the reviews editor of *BBC Focus Magazine*

TECHOMETER

WHAT'S HOT

VIRTUAL REALITY FILMS

The first commercial virtual reality headset, Samsung Gear VR, has just gone on sale. Film directors have already started experimenting with a medium in its infancy, with Sundance Film Festival hosting nine VR films in 2015. *Perspective; Chapter 1* will let viewers experience a social encounter from both sides, while *Project Syria* recreates scenes from the war-torn country. If that's all too heavy, *Birdly* claims to reproduce the sensation of natural flight.



WHAT'S NOT

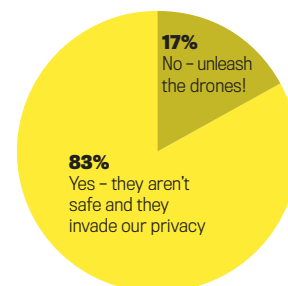
DRONES

You might have received a drone for Christmas, but the rules over where and how you can fly it are about to get stricter after an unidentified drone flew dangerously close to an Airbus A320 at Heathrow in summer 2014. The European Aviation Safety Agency is currently drawing up new rules, and is starting to prosecute hobbyists who flout the current laws.



READER POLL

Should laws concerning flying drones become stricter?



THE NEXT BIG THING

VIRTUAL FIELD TRIPS

TEACHING HAS already changed enormously thanks to the development of networked computers. We're now used to seeing screens in every class, with electronic whiteboards used to present lesson material. Textbooks are being replaced by tablets.

Since the advent of YouTube and iTunes U, teachers have been able to upload recordings of their own lectures and make them available to students, while sites like Khan Academy and the Open University's OpenLearn offer lectures and tutorial material from experienced academics.

Virtual reality systems are already being used in class, as teachers experiment with headsets like the Oculus Rift, or cheap and cheerful alternatives like Google Cardboard. Meanwhile, a primary school in Broughall, Eire built a model of a local monument in an OpenSim virtual environment. The pupils then used VR headsets to explore it in class.

With projectors and large screens becoming more affordable, schools may soon be able to give their students the experience of a field trip to the Amazon or Egypt without the need to travel. Soon, we will see classrooms turned into CAVEs. A CAVE – short for 'Cave Automatic Virtual Environment' – lets a group of people feel present in the same virtual environment at the same time, turning the classroom into a window on the real or computer-generated world.

The real transformation could come when we can simply wire students into a knowledge-dispensing



network. Military researchers in the USA have been experimenting with direct human-computer interfaces for years, using them to fly jet planes. Scientists at the University of Washington recently built a system that allows direct brain-to-brain communication, reading the electrical signals from one person's brain and sending a message – in this case a signal to move a finger – to someone else.

The signal is sent through transcranial magnetic stimulation, where electrodes on the skull generate a signal in the brain. Currently, it is unreliable and complicated, but it has the potential to become far more usable as we understand more about neural architecture and the brain.

I don't actually think we'll end up transferring real knowledge or concepts to another person this way, even if we overcome the enormous technical obstacles. But we might be able to take significant shortcuts to developing some motor skills, or create mental states that are conducive to understanding and learning.

Of course, we'll also need teachers able to embrace the technology and use it, unless we decide to give robots and AIs the responsibility for educating young people. But I can see lots of ways in which that could go wrong.



BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service

COMING SOON

3 MONTHS Samsung GALAXY S6 GALAXY S

Samsung's next flagship phone lands in April. Early leaks point to a 20MP camera, a better-than-HD screen and 3GB of RAM – tonnes of power to play *Candy Crush Saga*. Samsung.com

+ HTC One M9

Critics loved the One M8. Its successor, the M9, is due to arrive in early spring. A leaked photo suggests the phone will have a 5.2-inch screen with almost no bezel. Htc.com

+ Blackphone App Store

The high-privacy phone is rolling out an app store with software dedicated to keeping your personal info personal. Blackphone.ch

6 MONTHS

APPLE WATCH

Whatever you do, don't call it an iWatch. Apple's first new product since the iPad could grace your wrist as early as spring, but summer seems more likely. Apple.com



+ Tesla Model D

A sportier version of the *Focus* team's favourite electric car will roll on to European roads in the summer. We can't wait to try it out. Tesla.com

+ Oculus Rift

The virtual reality headset has been in development for the last two years, while competitors continue to release rivals all around them. A completed, consumer version of the Rift is expected to go on sale in July. Oculus.com

9 MONTHS

MARS SPEAKER

This device wouldn't look amiss aboard the USS Enterprise. Magnets hold the wireless speaker aloft in the air – it's a gimmick, but it's a cool one. Crazybaby.com



+ Ampy

This kinetic charger will convert 30 minutes of running into three hours of battery life for your smartphone. Getampy.com

+ Google Ara

This modular phone will let you pick and choose exactly what camera, battery and processor you want. We expect to see it towards the end of 2015 at the earliest. Projectara.com

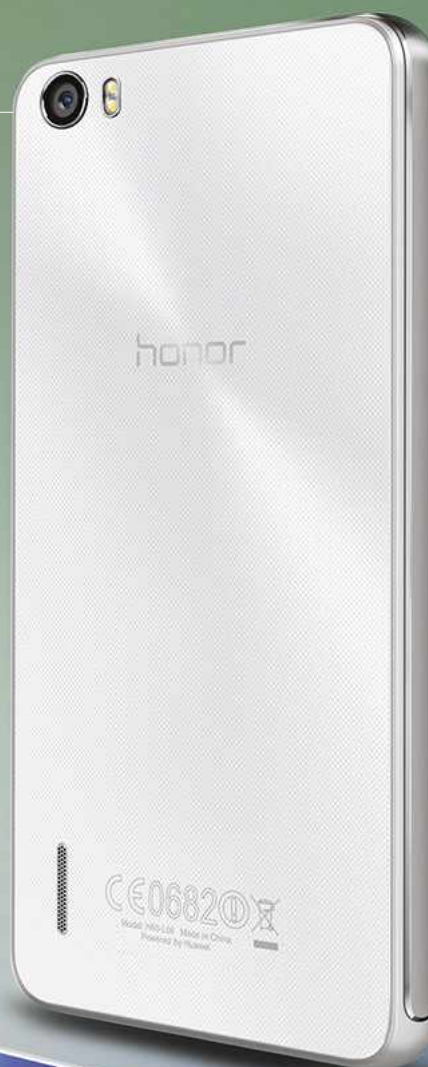


JUST LANDED: HONOR 6

CHEAP

AND CHIC

A new smartphone company is promising cheaper phones with bigger batteries. But does it deliver? **Daniel Bennett** finds out



HONOR 6,
HIHONOR.COM, £250

What's different about this phone?

On first impressions, this smartphone looks just like any other. But behind the standard design hides something more interesting. For a start, it's actually made by Huawei, the Chinese firm that's now the world's largest telecoms equipment maker. Huawei has struggled to match its success at home on foreign shores, so it's released a phone with features we've all been calling out for: a better battery and a cheaper price.

So how good is the battery?

On paper the stats look promising. The Honor 6 has a 3100mAh

battery – that's double the capacity you'll find in an iPhone 6. But it's not the size that matters, it's how you use it, so Huawei has included a patented SmartPower2.0 system that keeps an eye on the CPU's power consumption. Huawei says the Honor offers two days of "normal use". That may not sound like much, but we've never tested a smartphone with a battery that lasted more than 24 hours.

Sadly, the Honor 6 doesn't quite live up to its claims. The battery life is still good: over a busy weekend watching videos on the train and using the sat-nav and camera, the phone lasted the Saturday with 20-30 per cent to

spare. But it would have struggled to run on into Sunday without charging.

What about the phone's other vital statistics?

In terms of raw specifications, the Honor is up there with the best smartphones. It's got an octa-core processor inside it that's more powerful than my two-year-old laptop, which means that apps are responsive and the phone should work well for a few years. There's a 13MP camera at the rear and a 5MP

one on the front, and the pictures look great on the super-bright, full-HD screen, though the 'beautification' mode made me look like someone had taken a rubber to my face. What really stands out, though, is the price: £250. For that, you get the specifications and features of a Nexus 5 for £50 less, with expandable memory.

Should I buy one?

If you're looking for an Android phone, then it's hard not to recommend the Honor 6. There are some oddities in the interface, but no other Android device offers so much for so little. ■



APPLIANCES OF SCIENCE

1 NERDY NOSH

Turn the art of cooking into a science. The Pantelligent has a nifty built-in thermometer that tells your smartphone the precise temperature of its surface via Bluetooth. The Pantelligent app then uses this information to let you know exactly when to add your food to the pan, how long to leave it for and when you need to flip it, whether you're cooking the perfect steak or a risotto.

Pantelligent
\$199 (£127) plus P&P,
Pantelligent.com

2 LOOK MA, NO KEYS!

Who needs buttons anyway? The Sprout desktop PC has shunned a mouse and keyboard in favour of something more innovative. A projector beams images down onto a touch-sensitive mat, while a camera tracks your hand movements. This means that as well as using traditional inputs, you can edit photos with your hands, or turn real objects into virtual ones by placing them in the Sprout's view.

Sprout
£7BC, Sprout.hp.co.uk

3 FLYING SMALL FRY

The idea of taking your own personal drone cameraman on holiday might be appealing, but do you really have the space for a full-size quadcopter in your suitcase? The autonomous Zano drone fits in the palm of your hand and always flies within range of the smartphone to which it's paired. If you want to change the angle, simply point your phone in the direction in which you want the Zano to fly.

Zano camera drone
£169.95, Flyzano.com

4 BAND ON THE RUN

Every tech company in Silicon Valley is competing for space on your wrist right now. In order to stand out from the crowd, Microsoft has crammed every sensor under the Sun into its smartwatch. It'll tell you the UV levels, record your running routes, monitor your heart rate and more. Its real winning feature is that it works with all three main smartphone systems – iOS, Android and Windows.

Microsoft Band
\$199 (UK price TBC),
Microsoft.com

5 DINKY PRINTS

Standing at just 20cm tall, the iBox Nano is the smallest 3D printer in the world. Thanks to its size, it's also the quietest and most power-efficient 3D printer you can buy. And at a price of \$300 (£190) it's also the most affordable. But before you hand over your cash, just bear in mind that the prints are no bigger than a ping pong ball – perfect if you just happen to be a dolls' house enthusiast.

iBox Nano
\$300 (£190) plus P&P,
iboxprinters.com

6 TAKE NOTE

This special notebook blurs the line between the physical and the digital. It's been created to work with Adobe's Photoshop and Illustrator software. You draw a sketch on the notebook, take a picture with your iPhone and special markers on the paper help the app turn your scribbles into lines that you can then manipulate on Adobe software.

Smart Notebook, Creative Cloud Connected
£25.50 plus P&P,
Store.moleskine.com

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ULTIMATE TEST

RAISE THE BAR

Want to immerse yourself in a bubble of glorious surround sound? **Joe Minihane** tests four soundbars in the shops now...

SO YOU'VE SPLASHED out on a spanking new hi-def screen, but you can't bear the tinny sound emanating from its tiny speakers. Chances are you can't squeeze a home cinema setup into your front room, but don't fret – there is another way to hear every detail and have your ears pinned back after each explosion. Soundbars.

These all-in-one speakers sit under your TV or are mounted to a wall, delivering surround sound without having countless boxes dotted around the room. We tried four different devices to see how they sounded.



ARCAM SOLO BAR

£800
arcam.co.uk



Power output: 100W
Dimensions: 1,000mm x 130mm x 110mm
Connectivity: 4x HDMI input, 1x HDMI output, Optical, Coaxial, aptX Bluetooth, 3.5mm aux



ARCAM'S HUGELY IMPRESSIVE Solo Bar doesn't come cheap, especially if you choose to pair it with the Arcam Solo Sub, which costs an additional £500. But for that price you get arguably one of the best soundbars ever made. It has a large footprint, but its design and impressive array of connectivity put it well ahead of the crowd.

You can hook it up to your TV via optical or coaxial cables, or HDMI. The latter uses ARC

(Audio Return Channel) technology, which simplifies setup by sending video and audio using one HDMI cable. Only newer TVs have ARC, so check whether your television is compatible before you buy.

The sound from the Solo Bar, with and without the sub, is nothing short of sensational. While watching *Die Hard*, the explosions and over-the-top action were immersive without ever being overbearing. Meanwhile,

Matthew McConaughey's mumbling Rusty Cohle in *True Detective* was rendered clear and understandable – something no standard television speaker could ever manage. Using the on-board aptX Bluetooth, we were able to easily stream music from an iPhone and get astonishingly detailed sound. LCD Soundsystem's 'Tribulations' sounded deep and bassy, but never lost detail at the higher end.



SONOS PLAYBAR

£599 (soundbar only)
sonos.com

Power output: No details provided
Dimensions: 900mm x 140mm x 85mm
Connectivity: Optical, 2x Ethernet



WIRELESS MUSIC STREAMING company Sonos has been a byword for seamless listening for years. Its Playbar, therefore, was one of 2014's most highly anticipated pieces of audiovisual kit.

The Playbar differs from most soundbars in one major way: it has no HDMI ports, instead relying on an optical port to connect to the television. That's fine if you have a newer telly, but not if it's a few years old. However, there is an optical cable in the box. You will also need to

use the Ethernet cable to connect the Playbar to your router. Alternatively, you could splash out £39 for a Sonos Bridge to wirelessly hook up the soundbar to your TV. This means that you can use the free Sonos app, available on iPad, iPhone and Android, to stream your tunes from iTunes, Spotify, Napster and other services.

Music played through the device is nothing short of stunning – the screeching guitars and sparkling synths of St Vincent are a perfect

showcase for the nine amplified speakers. The audio is just as impressive when watching television. During *Breaking Bad* we easily picked up the tiniest background details and psychotic whisperings of Walter White.

The additional Sonos subwoofer costs £600. It can be positioned anywhere in your room and transforms the setup into a much more impressive 3.1 Surround Sound system.



THE SCIENCE BEHIND SOUNDBARS

BY THEIR VERY nature, soundbars cannot deliver complete surround sound in the same way that a separate speaker setup can. So in order to offer an experience close

to surround sound, manufacturers attempt to trick your ears into thinking you can hear noise from behind as well as in front of you. By directing the speakers so the

sound bounces off the walls to the side and behind you, soundbars are able to serve up something approaching surround sound. In the diagram, C represents sound

NAIM MU-SO

£895
naimaudio.com

Power output: 450W
Dimensions: 628mm x 256mm x 122mm
Connectivity: Optical, 1x Ethernet, aptX Bluetooth, 3.5mm aux



NAIM'S MU-SO DOES not come with any HDMI connectivity. But we're willing to forgive this oversight because it is primarily built for listening to music. That's not to say that it cannot sufficiently double up as a soundbar for your movie marathons. It most certainly can.

The Mu-so is shorter and chunkier than the others on test, so you'll need to have your TV mounted high to ensure the Mu-so doesn't block your view of the screen. But this is

a small issue to deal with when it serves up sound this good. It supports aptX Bluetooth, Apple AirPlay and Spotify Connect, playing every file format going.

We listened to Disclosure's 'Defeated No More' through the Mu-so soundbar and were completely blown away by the clarity and depth of the track. It felt as good as being in a nightclub, just without any sweaty punters getting in the way of our dancing.

Television setup is pretty simple and just involves hooking up the Mu-so soundbar via an optical cable. The soundbar works particularly well with action movies. We decided to go back to Arnold Schwarzenegger's over-the-top days with *Total Recall*. The movie had us pinned back in our seats with an aural assault that was as rounded as it was loud, which is just what you want when tuning in to '90s favourites.



PANASONIC SC-HTB680

£230 (soundbar and subwoofer)
panasonic.com

Power output: 350W (including bundled subwoofer)
Dimensions: 950mm x 110mm x 53mm
Connectivity: 1x HDMI input, 1x HDMI output, Optical



PANASONIC'S SC-HTB680 COMES bundled with a subwoofer. It offers an impressive 350W of output and you don't need to fork out for any extras. The SC-HTB680 has left, right and centre channels, which are bolstered by the subwoofer to offer a deep, rich sound that improves the speakers of today's super-slim TVs.

The svelte design looks the part, but the recessed cable ports are awkward to get to when you want to add new equipment to your

setup. The top display is hard to see when the soundbar is placed in front of a TV, meaning you can't see inputs and volume info from the sofa.

Like the Arcam Solo Bar, the SC-HTB680 supports ARC for simple connectivity. The sound is rich and bass-heavy, but it can feel a bit weedy when you don't have the subwoofer hooked up as well. This was especially noticeable when we played Caribou's album via the compatible Panasonic Music Streaming

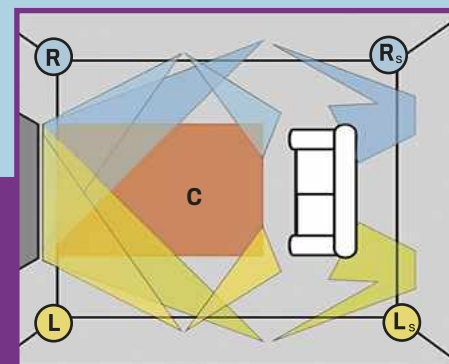
phone app. While the sound was clear and detailed, it lacked the same clarity as the – admittedly more expensive – Arcam and Sonos.



coming from the soundbar's main speakers, while L and R are the sounds for the left and right ears. L_s and R_s are sounds bouncing off the walls, giving a surround sound

effect. Room size and shape plays a part in how well this system works, and an additional subwoofer for bass will offer an even better experience.

JOE MINIHANE is a technology writer. He tweets from @joeminihane



THE CAUSE OF VOLCANIC ERUPTIONS

BY ANDREW ROBINSON

Volcanoes have been a major force in shaping the planet we live on – yet until quite recently, we knew surprisingly little about them

T

HE WORLD'S MOST recent major volcanic eruption – that of Mount Ontake in Japan, 200km west of Tokyo, in September 2014 – took hikers and scientists by surprise. More than 60 people were killed by ash, stones and poisonous fumes, yet scientific instruments located

around the volcano had given no signal of the coming explosion.

Tiltmeters and sensors connected to the GPS satellites – designed to measure the angle and elevation of the slopes – showed no change during the run-up to the eruption, or even while it was in progress. This indicated that there was no rise in molten rock, or magma, within the mountain. Seismometers showed a spike in activity about two weeks before the eruption, but this settled down at a rate of 10-20 small earthquakes per day: a level much lower than that of many Japanese volcanoes, such as the iconic Mount Fuji (which last erupted in 1707). A mere 11 minutes before Ontake's blast, seismometers detected a volcanic tremor: a type of seismic activity untypical of the earthquakes that frequently accompany eruptions.

The earliest human reference to volcanism is probably an enigmatic wall painting from the settlement of Çatalhöyük in Anatolia, western Turkey, which may show a volcano erupting over tightly packed houses – perhaps a depiction of neighbouring Mount Hasan's eruption in 6200BC. However, the first reliable references to volcanism date from ancient Greece and Rome. Plato accurately described the formation of lava or obsidian (volcanic glass): "Sometimes when the earth has melted because of the fire, and then cooled again, a black-coloured stone is formed," he wrote.

Aristotle, who coined the word 'crater' (Greek for 'cup') to describe the shape of volcanic summits, less accurately said that the fire beneath

the earth was the result of "the air being broken into particles which burst into flames from the effects of the shocks and friction of the wind when it plunges into narrow passages".

Famously, Pliny the Younger gave an eyewitness account, in AD 79, of the eruption of Mount Vesuvius that buried Pompeii and Herculaneum. The disaster killed his uncle, naturalist Pliny the Elder, when he went on a rescue mission to help Pompeii. Today, 'Plinian' is the term used to describe a Vesuvian type of eruption.

DIGGING FOR KNOWLEDGE

It is ironic that Pliny the Elder died as a result of an eruption. Although he compiled in his *Naturalis Historia* the earliest coherent list of active volcanoes, Vesuvius went unmentioned, presumably because it was not known to have erupted. In the following years, its danger was forgotten, along with Pompeii and Herculaneum. Only after another major eruption in 1631 (following six centuries of repose) were the towns rediscovered when wells were sunk during the rebuilding of modern Portici, which turned out to



This ancient wall painting from Çatalhöyük, Turkey, seems to depict a volcano erupting close to a human settlement



> IN A NUTSHELL

Plato gave us the first description of lava, but it wasn't until the late 18th Century with the work of William Hamilton and others that the study of volcanoes began in earnest. This led to our modern-day understanding of their role in shaping the planet.

Sicily's Mount Etna, pictured here in April 2013, is one of the world's most active volcanoes

→ lie on top of Herculaneum. Pompeii and Herculaneum were excavated from the 1730s onwards, and prompted the first stirrings of our understanding of volcanoes.

In the 1750s, French botanist Jean-Étienne Guettard recognised that the black stone used for construction in France's Auvergne region was similar to Italian rocks from Vesuvius and Mount Etna. He discovered that the stone in the French buildings was quarried at Volvic, a village south of Vichy. He guessed that 'Volvic' came from the Latin *volcani vicus*, 'volcanic village' – so it seemed that the Romans were aware of the connection, too.

Guettard visited the Volvic quarry and climbed the hill behind it. To his delight, a series of old volcanic cones stretched before him, now smooth and vegetated. In 1752, he delivered a paper to the French Academy of Sciences entitled *Memoir On Certain Mountains In France That Have Once Been Volcanoes*. Over the next few decades he and others, notably Nicolas Desmarest, studied and mapped a chain of 50 volcanoes in the Auvergne, the most famous being Puy de Dôme. We now know that the last eruption there occurred about 6,000 years ago.

Among those attracted to Vesuvius was William Hamilton, Britain's

ambassador to Naples from 1764 to 1800 (and husband of Emma, the mistress of Admiral Nelson). Vesuvius erupted violently nine times during Hamilton's stay; he made more than 200 sorties up its flanks, and became one of the pioneers of volcanology. He began to compile a list of eruptions, by collecting the dates on which the priests in Naples and the villages and towns around the volcano had displayed sacred images to ward off destruction. Hamilton was intrigued by the stolid philosophy of the locals: "Each peasant flatters himself that an eruption will not happen in his time, or, if it should, that his tutelar saint

THE KEY EXPERIMENT

Debate raged for a long time about how rocks are formed. It wasn't until the 1790s that simply melting and cooling rocks in a laboratory settled the argument for good

IN THE LATE 18th Century, there were two competing theories regarding the formation of terrestrial rocks. Neptunists, believers in the story of the Flood, maintained that most rock had been laid down as layers of sediment by the action of water. Vulcanists (or plutonists), after observing the material ejected by erupting volcanoes, proposed that some rocks had been melted by heat inside the Earth. But if they were right, and

so-called volcanic rocks such as basalt and granite had once been molten, why did these rocks show crystal structure rather than looking like glass, like the mineral obsidian?

Experiments by James Hall in the 1790s suggested the reason. Hall took samples of whinstone – the name given to basalt in his area near Edinburgh – and melted them in an iron foundry. He called the molten substance 'magma'. When cooled quickly, magma turned

to glass. Cooled over several hours, however, it reverted to crystalline rock very similar to whinstone. By varying the time of cooling, Hall could vary the size of crystals. He repeated the experiments with six lava samples from Mount Etna, Mount Vesuvius and Iceland. Whinstone and lava, Hall noted in 1800, "agree so exactly in all their properties... as to lead to a belief of their absolute identity".



This micrograph of a basalt rock sample clearly shows the crystalline structure, which obscured the rock's volcanic origins until Hall's experiments shed new light on the matter

will turn away the destructive lava from his ground; and, indeed, the great fertility of soil in the neighbourhoods of volcanoes tempts people to inhabit them," he wrote. Hamilton's letters to the president of the Royal Society in London, published in 1772, became the first modern work of volcanology.

SOLID THEORIES

Neither Guettard nor Hamilton proposed a theory of volcanism, however. At this time, the dominant idea was that rocks were of sedimentary origin and had been laid down in layers by the biblical Flood. Volcanic activity was therefore a recent and superficial phenomenon – merely the result of veins of coal catching fire underground and burning their way to the surface. Indeed, the word 'volcanic' only entered the English language in 1774.

In the 1780s, James Hutton – the so-called father of modern geology – carried out field observations in Scotland. His work, along with rock experiments by his friend James Hall in the 1790s, made it clear that many rocks were of igneous origin. They were formed not by water, but by being melted within the Earth and extruded at the surface through volcanoes (see 'The Key Experiment').

Hutton's idea of a dynamic Earth with a molten interior was elaborated by Charles Lyell in his *Principles Of Geology*, published in 1830-33. This strongly influenced Charles Darwin's interpretation of active volcanoes in South America as the agent of mountain building, and of extinct underwater volcanoes in the Pacific as the foundation of coral islands. The idea was firmly established by 1883, when the Indonesian island of Krakatoa erupted for 100 days, ending with a titanic blast that destroyed the volcano and sounded like gunfire nearly 5,000km away. It generated both a tsunami that annihilated 36,000 people, and an ash cloud that caused global atmospheric effects for years.

A scientific expedition from Europe landed on the remains of the island less than two months later. The ejecta thrown out by the eruption, when analysed in a laboratory, turned out not to belong to the rock of the old volcanic cone, but to be newly solidified magma from deep down. The expedition's Dutch leader, RM Verbeek, decided that Krakatoa

CAST OF CHARACTERS

Some of the key players in the birth and evolution of the science of volcanology



Jean-Étienne Guettard (1715-86) was a French geologist and mineralogist, who began his career as a botanist. He created the world's earliest geological map, based on his survey of France. In the 1750s, he was the first to recognise the volcanic origin of the mountains in the Auvergne region of central France.



William Hamilton (1731-1803), a Scottish diplomat, served as the British ambassador to the Kingdom of Naples from 1764 to 1800, a period that coincided with frequent eruptions of Vesuvius, which Hamilton observed and reported at close quarters. In effect the first volcanologist, he received the Royal Society's Copley Medal of Britain in 1770.



James Hall (1761-1832), as the son of a wealthy Scottish landowner, was free to pursue his interests in geology and chemistry. Touring Europe in 1783-86, he climbed Vesuvius five times. Back in Scotland he became a friend of James Hutton, whose geological observations Hall later confirmed by laboratory experiments.



Alfred Lacroix (1863-1948) was professor of mineralogy at the National Museum of Natural History in Paris. Co-author of a pioneering work on the optical properties of rock-forming minerals, he is best known in volcanology for his detailed investigation of the 1902 eruption of Mount Pelée in Martinique, which was published in 1904.



John Tuzo Wilson (1908-93), a Canadian geophysicist and geologist who reached the rank of colonel during World War II, was a key contributor in the 1960s to the theory of plate tectonics, which transformed volcanology. He also proposed the hot-spot theory to explain the volcanic origin and continuing volcanism of the Hawaiian Islands.



TIMELINE

How our understanding of the nature of volcanoes has developed over the past 250 years



1752 Evidence for Europe's volcanic origin is submitted to the French Academy of Sciences, based on a survey of mountains in the Auvergne by Jean-Etienne Guettard.

1752



1772 William Hamilton, inspired by Pompeii's excavation and the activity of Vesuvius, publishes *Observations On Mount Vesuvius, Mount Etna And Other Volcanos*, the first scientific report on volcanic eruptions.

1772

1790s The concept of magma is introduced by James Hall, as a result of laboratory experiments on the melting of igneous rocks, including basalt (or 'whinstone') from Scotland and lava from active volcanoes in Europe.

1790s



1883

Krakatoa's explosive eruption in Indonesia creates an ash cloud with global atmospheric effects, including brilliant sunsets in London. A scientific investigation of the eruption is published by Britain's Royal Society.



1902 The eruption of Mount Pelée in Martinique incinerates neighbouring St Pierre. The French scientific report that follows introduces the concept of a *nuée ardente* ('burning cloud'), later renamed as a pyroclastic flow.

1902

1963 The hotspot theory proposed by John Tuzo Wilson explains the volcanic history of the Hawaiian Islands in terms of a moving tectonic plate and a stationary hot spot created by a mantle plume.



1963

➔ had ejected its magma chamber into the air, and the space had then been filled by the cone's collapse, creating a caldera or giant crater. He further suggested that seawater penetrating the magma chamber had provoked the mega-blast.

Today, Verbeek's first idea is generally accepted, but not the second. The mixing of magma and seawater usually gives rise to a distinctive deposit of very fine-grained, widely dispersed ash. No such deposits have been found at Krakatoa. Rather, the current view is that the main blast was caused by the violent mixing of two magmas: a basaltic magma injected beneath a denser, dacitic magma. The first magma, being less dense, rose buoyantly and abruptly, and an explosion resulted. The presence in the ejecta of both types of magma, in different proportions at different times during the eruption, supports this view.

FATAL FLOW

The cause of Krakatoa's tsunami is less clear. Some scientists have suggested an underwater explosion. Verbeek favoured either the slumping of the cone into the caldera, or the sudden displacement of water by hot gases and rocks 'falling' into the sea: in other words, what is now termed a pyroclastic flow. Such flows are a common and deadly feature of certain volcanoes. Pyroclastic flows probably smothered Pompeii and Herculaneum; they certainly occurred as a result of the lethal 1902 eruption of Mount Pelée in Martinique, where they were observed for the first time by scientists cruising past the ruins of the port of St Pierre in a sailboat.

"The cloud was globular, with a bulging surface covered with rounded protuberant masses which swelled and multiplied with terrible energy," the scientists wrote. "It rushed forward over the waters, directly towards us, boiling and changing its form every instant. It did not spread out laterally; neither did it rise into the air but swept on over the sea in surging masses, coruscating with lightning." The original term for the phenomenon, *nuée ardente* ('burning cloud'), was given by Alfred Lacroix in his scientific report on Pelée's eruption.

With the introduction of plate tectonic theory in the 1960s, it at last became clear why volcanoes and earthquakes occur in certain areas.

NEED TO KNOW

A quick glossary of some key terms used in volcanology

1 MAGMA

Magma is a Latin term for molten rock, first used in chemistry to mean a pasty substance. Magma is formed at high temperatures inside the Earth, either within the upper mantle or at tectonic plate boundaries. It rises buoyantly into the crust to form pools, sometimes called magma chambers, which feed volcanoes.

2 IGNEOUS ROCKS

Igneous (from the Latin for 'fire') refers to rock formed either by the cooling and solidification of magma inside the Earth, such as granite, or by extrusion of lava on the surface through volcanic action, such as basalt. The most common volcanic rocks are basalt, andesite and rhyolite, in increasing order of silica content and viscosity.

3 PYROCLASTIC FLOW

Whereas a lava flow consists of molten rock, a pyroclastic flow (from the Greek for 'fire' and 'broken into pieces') is a fast-moving current of hot gas and rock, both solid and molten. Hugging a volcano's slopes and then spreading under gravity, pyroclastic flows can reach temperatures of as much as 1,000°C and speeds of up to 700km/h.

Where tectonic plates touch, the less dense plate is elevated and the more dense plate is subducted, for example beneath Japan. However, at volcanic rifts – such as the Mid-Atlantic Ridge – plates grow and begin moving as new rock is created by the extrusion of magma from the upper mantle.

However, plate tectonics did not give a coherent explanation of intraplate volcanoes, such as those in the Hawaiian Islands. So John Tuzo Wilson came up with his hotspot theory in 1963. According to this idea, the Hawaiian Islands were formed by a stationary, plume-shaped mass of magma rising from deep in the mantle and punching a hole in the Pacific plate as the plate moved in a northwesterly direction. If this is correct, the Hawaiian hotspot should have created a string of volcanoes trending to the northwest – each active



The September 2014 eruption of Mount Ontake in Japan claimed over 60 lives, and occurred without any warning

for a while, then becoming extinct as it moved away from the hotspot. Its rocks should get older the further away the extinct volcano is from the hotspot's present site beneath Hawaii's Big Island. This is indeed the case. The rocks of the Hawaiian Islands do age towards the northwest, and there is a series of sunken, extinct volcanoes beneath the Pacific – the Hawaiian Ridge and the Emperor Seamounts – that trails off over 5,600km of seafloor towards the Aleutian Islands.

The rocks of extinct Kauai, the northernmost Hawaiian island, are five million years older than those of the Big Island, according to radioactive dating of ancient lava flows. This age agrees with the age predicted by the speed at which the Pacific plate is believed to be moving. The Hawaiian hotspot has generated some 200 volcanoes over 75 million years.

Vital though our understanding of volcanic eruptions is, it cannot forecast the behaviour of the world's 1,300 potentially active, landlocked volcanoes. Only constant monitoring of each volcano may provide this information. It saved thousands of lives in 1991, during the eruption of

Mount Pinatubo in the Philippines. But it failed at Mount Ontake in 2014. Ontake erupted in 1979, 1991 and 2007, also without prior magmatic activity, although insufficient instrumentation was in place in 1979 and 1991 to rule this out.

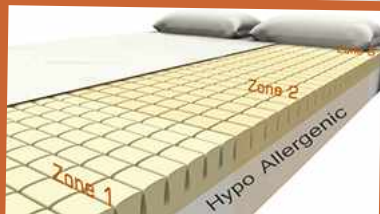
Now, volcanologists charged with monitoring Japan's 110 active volcanoes are wondering if Ontake could be getting ready for a magmatic eruption. The problem is that this volcano does not have an easily predictable cycle. "It's a very quiet mountain," Toshikazu Tanada cautiously noted after the 2014 eruption. "Each active volcano has its own characteristics." ■

ANDREW ROBINSON is the author of *Earthshock and Earthquake: Nature And Culture*

Find out more



Discover information, photos and videos of volcanoes on BBC Science online. <http://bbc.in/LULg38>



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PICK OF THE MONTH



Kate Humble Into the Volcano

Kate Humble voyages to the South Pacific – and peers into the abyss

➔ VANUATU IS A chain of 83 islands in the South Pacific, named the New Hebrides by Captain Cook (who was the third European to 'discover' and name them). Handy for pub quizzes, less handy for tourists, as the nearest large land mass – Australia – is over 1,750km away. If you've ever heard of the Pacific Ring Of Fire, you'll know it's not a particularly spicy fusion cuisine, but an arc of volcanoes that follows the edges of the ocean's tectonic plates. These are the very same volcanoes that created many of the Pacific Ocean's inhabited islands, including Samoa, Fiji and Vanuatu itself.

For the BBC TV programme *Into The Volcano*, a team of geologists, anthropologists, linguists and volcanologists arrive on the islands with presenter Kate Humble. They meet the people who call the islands home, encounter the unique wildlife, and occasionally battle through the dense jungle. Their aim is to get up close and intimate with two of Vanuatu's most explosive volcanoes.

First, Mount Yasur, on the island of Tanna, claims the title of 'world's most accessible active volcano'. Tourists are treated to a display of ash, molten rock and superheated steam. Known locally as the Old

Man, Yasur has inspired a rich tapestry of beliefs and traditions, one of which is the Prince Philip Movement. Kate goes in search of its members, who believe that the Duke of Edinburgh is the son of a volcano spirit who ventured overseas to marry a powerful woman. But there's no time for Kate and her team to sign up. They're off to the island of Ambrym, home to the Marum crater – a bubbling cauldron of incandescent lava. Here, they undertake a daring mission, abseiling right into the heart of the deadly crater.

Of course, the real hope is that by better understanding the volcanoes' habits, the scientists will be able to predict the next major eruptions, saving the lives of locals and reckless tourists alike.

Oh, and the largest volcano of Vanuatu – Ambae – was immortalised in the musical *South Pacific* as Bali Ha'i. See? Always learning.

TIMANDRA HARKNESS



Kate Humble: Into the Volcano airs on BBC Two in January. Check radiotimes.com for full details

DON'T MISS!



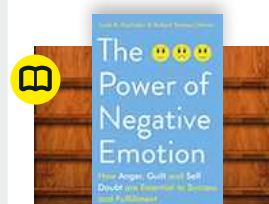
Bloodfest

Dr Michael Mosley's latest programme takes a closer look at the life-giving fluid that courses through all our veins. **p100**



Lifelogging Lab

Find out why and how more and more people are logging every aspect of their daily lives. **p103**



The Power Of Negative Emotion

In the 1980s, greed was good; now, it's guilt and anger. Find out why in this new book. **p104**



WATCH

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WITH TIMANDRA HARKNESS

JANUARY

10,000 BC

Channel 5, dates and time TBC



YOU KNOW HOW we're not really that different from our cave-dwelling ancestors? Well, while we wait around for scientists to clone the first Neanderthal, some television producer thought they'd send 20 people back through time to live in the Stone Age. What happened was not like *The Flintstones*. We're preparing for tantrums...

JANUARY

Time Scanners

Channel Five, dates and times TBC



HOST DALLAS CAMPBELL (pictured) and engineer Steve Burrows get under the Earth's surface without even lifting a trowel. Laser scanning uncovers the secrets of the Egyptian pyramids, allowing the team to create 3D virtual models of the relics. Burrows traces their development from primitive tombs to the Great Pyramid of Giza.

FROM 18 JANUARY

Street Genius

National Geographic, 6pm



Tim Shaw, pictured on the right

THE SERIES FORMERLY known as *None Of The Above* is back. Tim Shaw resumes his mission to demonstrate science by challenging strangers to predict what happens next. How many water balloons will it take to stop a bullet? What's the best protection from lightning? He then involves them in an experiment that will discover the answer.

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel *Head Squeeze*

EDITOR'S CHOICE



Michael Mosley - prior to the Vampire Facelift, we assume

JANUARY

Bloodfest

BBC Four, dates and times TBC

LAST TIME WE spoke to Dr Michael Mosley, there was a tapeworm living in his intestine. The tapeworm, it turned out, was his latest co-presenter in a television show called *Infested! Living With Parasites*. Mosley explained that he'd decided to eat a tapeworm cyst in order to find out what effect parasites have on the human body.

Since that last show, Mosley has been experimenting on himself once again. His brand new programme, *Bloodfest*, is all about, you guessed

it, blood. More specifically, Mosley investigates the ways in which new clinical trials are manipulating the red stuff to help heal our bodies.

As we know, Mosley is not shy of putting his body on the line in the name of medicine. Here, he visits a plastic surgeon who offers him a Vampire Facelift - no prizes for guessing what substance the procedure uses. He also goes to a laboratory in Norway where he discovers the effects that diesel emissions are having on his health.

FROM 19 JANUARY

Survivors: Nature's Indestructible Creatures

Eden, 8pm



Crocodiles: extreme survivors

YOU MAY THINK you've done pretty well to survive a family festive season, but some species have been around for millions of years. In this three-part investigation, Prof Richard Forrey of London's Natural History Museum unearths the stories of some extreme examples to find out what enabled them to keep going when the dinosaurs came and went.

24 JANUARY

Dolphins: Spy In The Pod

Eden, 5pm



THIS SERIES FOLLOWS the success of *Penguins: Spy In The Huddle* with gadgets like 'spy clam', 'spy turtle' and 'spy squid' that film dolphins from close up. What better Saturday teatime viewing than some happy aquatic mammals going about their family lives, politely ignoring the weird robot creatures filming their every move?

24 JANUARY

Ghost Planes And The Mystery Of Flight 370

H2, 7pm



Why did Malaysia Airlines Flight 370 go missing?



IN A WORLD where everything can be tracked, photographed and mapped on GPS, and commercial aeroplanes often rely on electronic communication, how easy can it be to lose a plane? Surprisingly easy, it seems. Malaysia Airlines Flight 370 is one of more than 80 aircraft that have vanished without trace since 1948. This two-hour special looks at some of these intriguing cases, and invites experts to share current theories about what happened to the flight from Kuala Lumpur to Beijing.

DVD & BLU-RAY



Marie Curie

Danann Publishing, £26.75

FIRST SHOWN ON BBC One back in 1977, this tells the story of the Nobel prize-winning chemist. It stars Jane Lapotaire and Nigel Hawthorne.



Dinosaur 13

Dogwoof, £11

THIS FEATURE-LENGTH documentary tells how Peter Larson and his team unearthed the largest *T. rex* skeleton. But far from being an instant ticket to fame, it was the start of a 10-year nightmare.

ONLINE

YOUTUBE

Monica Grady: Seven Wonders Of The World

<http://bit.ly/1z5JsYi>


DID YOU ENJOY seeing planetary scientist Professor Monica Grady's reaction during the Rosetta landing? Here's half an hour of the meteorite expert from a BBC science series back in 1995.

YOUTUBE

Cantor And The Infinite

<http://bit.ly/1xOWJg8>


INFINITY COMES IN different types and sizes, as concisely explained in this taster for Professor Raymond Flood's lectures on mathematics. More free lectures are available at gresham.ac.uk

YOUTUBE

Behold The Sci-Ku Girls!

<http://bit.ly/1x0Ydxb>


STUDENTS FROM CAMDEN School for Girls wrote these science haikus to raise money for new school labs. Here's our haiku: Awesome! good cause, these girls perform their poems, funding science labs.



LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

FROM 12 JANUARY

The Diaries Of Brett Westwood

BBC Radio 4, 1.45pm

NATURALIST AND PRESENTER Brett Westwood started writing his wildlife diary as a teenager nearly 40 years ago. In this radio programme, he goes back to see what's changed. Buzzards and otters have moved in, cuckoos and water voles moved out – but not completely, he finds.



Water voles have declined in numbers

13 JANUARY

The Human Zoo

BBC Radio 4, 3.30pm

MICHAEL BLASTLAND JOINS behavioural expert Prof Nick Chater from the University of Warwick to think about thinking. The pair uses experiments and expert interviews to turn the spotlight on the inside of the human mind.

FROM 17 JANUARY

Exchanges At The Frontier

BBC World Service, various times

RECORDED WITH A live audience at London's Wellcome Collection, this features a series of conversations with leading scientists about their work and what it means. Hear about emotions in decision-making, robots on Mars, cancer in the human genome and IVF for coral reefs.

29 JANUARY

The Sound Of Space

BBC Radio 4, 11am

ASTRONOMER LUCIE GREEN takes time out from watching the skies to listen to them instead. In space, nobody can hear you scream. Not if you're still on Earth, anyway. Unless you're Skyping the ISS. But what can *they* hear?



Astronomer Lucie Green explains the sounds of space in this radio programme

ONLINE

The Libet Experiment: Is Free Will Just An Illusion?

bbc.co.uk/programmes/p02b8y3f



THIS IS JUST one of a delightful series of BBC Radio 4 animations called *A History Of Ideas*. Melvyn Bragg enlists some powerful thinkers to discuss philosophers and their work.



PHOTO: ISTOCK



TOUCH

SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

Brainfeed

iOS 6.1 or later, iPad, Brainfeed LLC, free



KIDS ASK SOME challenging questions. Is time travel possible? Does space go on forever? Why do people grow old? *Brainfeed* replies with handpicked videos from the web, covering topics from across the scientific spectrum. Content is screened to be suitable for ages

seven and older, and is in line with curriculum studies. Some of the content is free, but you'll need a premium subscription to unlock the whole library of 1,250 videos.

Be A Martian

iOS 6.0 or later, iPad/iPhone/iPod Touch, NASA, free



THERE IS ALWAYS a lot of talk about off-world exploration, but you can beat everyone to Mars if you download *Be A Martian*. This app delivers everything you could want to know about life on Mars, drawing on NASA's incredible archives of videos, images and data from the various landers and probes already sent to explore the Red Planet. *Be A Martian* includes raw footage courtesy of the landers, along with mission details and full planetary specs. You'll be as

prepared as anyone to step foot on Mars, and all without splashing out on a one-way ticket across the Solar System.

iGeology 3D

Android 2.1 or later, British Geological Survey, free



BENEATH MY FEET right now are clay, silt, sand and gravel deposits formed up to five million years ago. Just across the field I can see a band of sedimentary bedrock that was formed around 100 million years ago.

Nope, I haven't developed X-ray vision – I've downloaded *iGeology 3D*. This app lets budding explorers look around their surroundings using their smartphone's camera. It then uses augmented reality to overlay the British Geological Survey's detailed maps onto the UK landscape in a semi-transparent layer. Tap on a section of the map to see detailed information about the composition of the ground beneath the image.

KATE RUSSELL is a technology journalist and BBC *Click* presenter



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN



22 JANUARY

The Blue Planet In Concert

Royal Festival Hall, London, 7.30pm, £15-£55

ENJOY THE PHILHARMONIA Orchestra playing the majestic score to the classic BBC nature documentary *Blue Planet*, synchronized with breathtaking footage from the series.

28 JANUARY

Quantum Biology: An Introduction

Royal Institution, London, 7pm-8.30pm, £12, rigb.org

IN THE FIRST of three talks hosted by Jim Al-Khalili, Philip Ball explains the role the subatomic world might play in biological processes.



4 FEBRUARY

Extreme Volcanic Eruption

University of Bath, 5.15pm, free, www.rgs.org

FORGET A NEW Cold War, a natural disaster is far more likely to destroy us. Prof Stephen Sparks explains how a super-eruption could be 100 times larger than the biggest in the last 1,000 years.

5 FEBRUARY

Global Catastrophes: A Very Short Introduction

Bootham School, York, 7.15pm-8.30pm, £3, www.rgs.org

FLOODS AND HEATWAVES are bad enough, but climate change could lead to far worse disasters, as Prof Bill McGuire explains.



10 FEBRUARY

Incoming!

Royal Astronomical Society, London, 6pm-7pm, www.ras.org.uk

A SINGLE METEORITE didn't wipe out the dinosaurs on its own, says geoscientist Ted Nield, who outlines other factors in this talk.

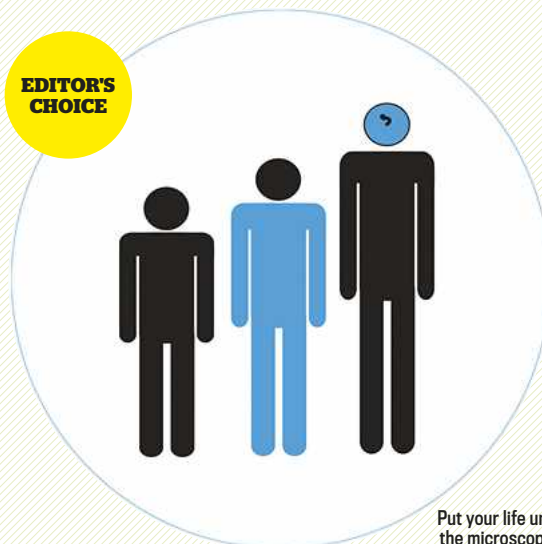
13 FEBRUARY

Cravings: Can Your Food Control You?

Science Museum, London, free, sciencemuseum.org.uk

WHAT DO YOU crave? Caffeine? Chocolate? A fry-up? Learn how appetite is shaped by food, how the brain and gut work to control it, and how our senses trick our brains into wanting more.

EDITOR'S CHOICE



Put your life under the microscope at Lifeloggging Lab

FROM 12 FEBRUARY

Lifeloggging Lab

Science Gallery, Dublin, free, dublin.sciencegallery.com



WE'VE BEEN TO the Moon, we've dived to the depths of the Mariana Trench, we're drilling to the Earth's mantle. Now it's time to explore ourselves. Part exhibition, part laboratory experiment, Lifeloggging Lab sets out to explore "the remaining frontiers of data science, bio-data collection and data visualisation". Using cutting-edge equipment, there will be the opportunity for you to explore and record your life in detail using data analysis and various visualisation techniques.

UNTIL 14 FEBRUARY

War, Art And Surgery

Hunterian Museum, London, www.hunterianmuseum.org

EXPLORE THE LINK between war and surgery through the work of artist Julia Midgley, who has had access to WWI military facilities.



15-16 FEBRUARY

Meccano Comes Home!

Museum of Liverpool, 2pm/3pm, liverpoolmuseums.org.uk

DID YOU KNOW that Meccano was invented by Liverpool's Frank Hornby, of model railways and Dinky Toys fame? Get hands-on with Meccano at this two-day event in its birthplace.

17 FEBRUARY

Bright Club

The Stand Comedy Club, Newcastle, 8pm-10pm, £4, thestand.co.uk

IF YOU LOVE comedy, music, performance and science, then don't miss this night out. Brave performers take on eight-minute slots on any subject - unpredictable entertainment is guaranteed.



READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback **P** Paperback

The Power Of Negative Emotion

How Anger, Guilt And Self-Doubt Are Essential To Success And Fulfillment

Todd B Kashdan and Robert Biswas-Diener

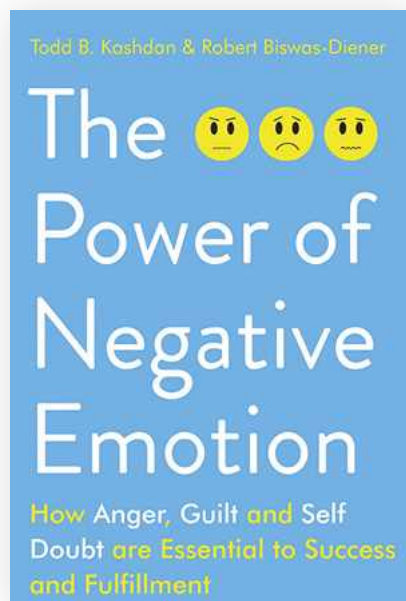
Oneworld **P** £8.99

WE'VE BECOME ADDICTED to comfort. We run from emotional and physical pain, and at the first sign of boredom or sadness we reach for a distraction. This is no way to live, argue US psychologists Todd Kashdan and Robert Biswas-Diener. To be truly happy, to be 'whole', they say we need to embrace our dark sides.

To support their argument, the pair turn to an assortment of fascinating, if highly selective, psychology findings. Consider the fact that workers achieved a 400 per cent better success rate on an analytical task when their leader showed signs of sadness – sadness is known to encourage a focused, analytical thinking style.

We should see our emotions, both negative and positive, as tools that help us in different contexts, say the authors. For example, getting angry in a controlled manner can help you negotiate, while feeling sad can improve your lie detection

“People high in psychopathic traits were more likely than others to help a stranger in distress”



abilities. Even the maligned personality trait of psychopathy has its upsides – one study found that when given the chance to display heroism, people high in psychopathic traits were more likely than others to help a stranger in distress.

Yet the book sometimes undermines its own premise that we need help reconnecting with darker emotions. For instance, the authors describe research showing that people know intuitively that it helps to feel sad when attempting to obtain charity donations. Elsewhere, as part of an extended critique of 'mindfulness' (being focused in the moment), Kashdan and Biswas-Diener explain the benefits of mindless mimicry, saying that it helps us in social interactions. But as they say, this behaviour is 'mindless' – it comes naturally.

This book is enjoyable, but the scientific content has been packaged awkwardly into a questionable self-help message. Kashdan and Biswas-Diener speak repeatedly of using negative emotions to find "true success" and "to progress on your journey of personal growth". Yet they don't spell out what they think this successful life consists of – other than it means embracing our dark traits, which is a circular argument.



CHRISTIAN JARRETT is a psychology writer. His latest book is *Great Myths Of The Brain*

MEET THE AUTHOR



Todd B Kashdan

Many people would say that the key to feeling happy is to maximise positive emotions. Is that not right?

The bulk of the emotional experiences that we want to feel in our lives are things like hope, tranquility, compassion, love and gratitude. But happiness is actually a very problematic outcome to have for your life. The research says that when we overvalue the importance of being happy, it actually makes it more difficult to become happy in the first place.

So are there any benefits to, for instance, feeling angry?

Anger is incredibly useful. Some people who are in romantic relationships say they don't fight, and I always get worried. There are so many reasons to fight and disagree, and if you don't express your frustration, your partner will never know what makes you feel disrespected, deflated or unfairly treated. A study in the 1980s found that more than 75 per cent of people who were the target of someone else's anger gained a better understanding of their own strengths and flaws.

What should we do when we feel negative emotions?

Instead of asking, "How can I feel better?" ask yourself, "Does this emotion have a purpose for the situation I'm in?" When we're feeling sad or anxious, we're ready to do something challenging and be a bit more sceptical about what other people are saying. Our emotions are telling us that there's something to be wary of. When we're happy, we tend to be lazy in our thinking. Evolution has designed us with this broad emotional repertoire, and we should honour that.

MORE ON THE PODCAST

Listen to the full interview with Todd B Kashdan at sciencefocus.com/podcasts



Do Zombies Dream Of Undead Sheep?

A Neuroscientific View Of The Zombie Brain

Timothy Verstynen and Bradley Voytek

Princeton University Press £13.95

HOW DO YOU make a tough subject like neuroscience accessible to a young audience? Researchers Verstynen and Voytek attempt to do just that by comparing brains of normal humans to the hypothetical workings of zombies' brains. They systematically work through various brain-supported functions such as sleeping, eating, walking and talking, and then investigate how such abilities are abnormal in zombies.

Zombies are easily distracted by sudden flashes and loud bangs. The authors propose that this is because the brain systems that enable normal humans to focus their attention no longer function correctly. Similarly, the lumbering gait seen in zombies could be the result of problems with motor function.

The science is pretty accurate, but the continual reference to zombies eventually becomes tiresome, as do the puns and frat house writing. Still, the authors seem to have pitched the book at the right level for their audience, and they could be on to a good seller. After all, the zombie craze doesn't seem ready to die just yet.



BRUCE HOOD is a psychologist and the author of *SuperSense* and *The Self Illusion*



The Glass Cage

Where Automation Is Taking Us

Nicholas Carr

Bodley Head £20

EDITOR'S CHOICE

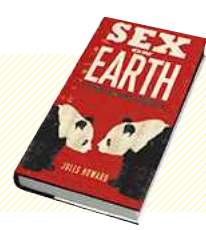
MY COPY OF this excellent book is so thoroughly scribbled on that I'd simply never be able to get rid of it. I've circled lots of stuff I agree – or disagree – with, and added exclamation marks to insights that I want to explore more deeply.

Carr examines the history of automation, from aircraft navigation to factories, farms, and driverless cars. By the time he's finished, you too will be worried that our unfettered faith in 'progress' has allowed technocrats and entrepreneurs to build systems which may serve their need for profit and control, but rarely serve our needs as humans.

The final section of the book is beautifully written, especially when Carr looks to the poetry of Robert Frost for inspiration as he discusses the way we have lost any direct connection to our tools. *The Glass Cage* is infused with a humanist perspective that puts people and their needs at the centre of the argument around automation and the alienation created by many modern systems. He doesn't have many answers, but believes that it's not too late to ask the questions. So put down your phone, take off your Google Glass and read this.



BILL THOMPSON contributes to the BBC World Service and news.bbc.co.uk



Sex On Earth

A Celebration Of Animal Reproduction

Jules Howard

Sigma £16.99

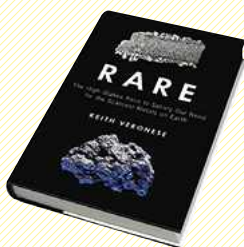
A COUPLE OF sidelong glances from fellow travellers on the London train had me slipping off this book's somewhat lurid dust jacket: the word 'sex' must stand out more than the slightly doleful pair of pandas beneath. Still, attitudes have certainly improved over the 100 years since, as Jules Howard recounts, explorer George Levick described the sexual high jinks of Adélie penguins he'd observed in Antarctica. And this book does an admirable job of separating the scientific from the merely smutty.

The reader is led through a cornucopia of animal breeding strategies, from racehorses to fen raft spiders, via hedgehogs, flamingos and slugs. And the most fundamental question of all – why is sex so ubiquitous? – is addressed in a chapter enticingly entitled 'Sexless Zombie Time-Travellers'. It describes a group of asexual animals I found I knew very little about, the bdelloid rotifers. There's even a chapter at the end about love (mainly jackdaws and prairie voles, with a smidgen of human thrown in).

This book is highly entertaining and informative, as well as being prurient – for all the right reasons.



JOHN BRADSHAW is an animal expert and author of *In Defence Of Dogs* and *Cat Sense*



Rare

The High-Stakes Race To Satisfy Our Need For The Scarcest Metals On Earth

Keith Veronese

Prometheus £19

PROMETHIUM IS A radioactive metal that could potentially power atomic batteries that last for decades. But there is just half a kilogram of it spread throughout the Earth's crust, making it one of the rarest elements on the planet. This, of course, makes it incredibly desirable. Tantalum, rhodium, osmium and niobium are similarly in demand for use in smartphones, laptops and even weapon systems. These scarce but highly sought-after elements are increasingly underpinning our world.

Rare is one of the first books to explore our insatiable appetite for certain metals. It takes us on a journey from the brutal

battlefields of the Congo, where demand for tantalum, tungsten and tin fuel bloody conflict, to the hunt for metal-rich bedrock beneath Greenland's receding ice sheets.

The underlying science is accessible and is deftly combined with comments on the often-overlooked societal implications of the planet's chemical make-up. Viewed as a kind of 'essential guide' to crucial elements, *Rare* outlines their increasing geopolitical importance in the modern world.



PROF IAIN STEWART is a geologist and a BBC science presenter

NEXT MONTH

2015

BRITAIN'S

MOST DANGEROUS ROADS



A statistician reveals the roads where you're most, and least, likely to have an accident... and what you can do to reduce the risk. **On sale 5 February**

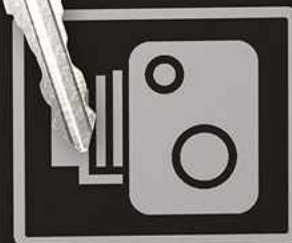




Photo Credit: Jon Savage Photography

DUNBAR SCIFEST 2015

7TH-8TH MARCH

At the 5th award winning annual community science festival, Dunbar SciFest weekend (Saturday 7th and Sunday 8th March 2015), enjoy entertaining stage shows and interact with scientist's delivering drop-in sessions and hands-on workshops. For under-fives, there's storytelling and soft play. Join four Nights of Light - "The Magic Lantern" at Barns Ness Lighthouse, Thursday 5th - Sunday 8th March and our adult programme evening events are on Thursday 12th - Sunday 15th March. Weekend Family Tickets: 1 day @ £15 and 2 days @ £20.

www.dunbarscifest.org.uk
help@dunbarscifest.org.uk



IMPERIAL FESTIVAL

9TH-10TH MAY

Make a date with discovery at the Imperial Festival this May, back for its fourth year and now extending over a full weekend. Bringing you ground-breaking research, music and art, talks, dance and comedy, this festival is free and open to all. Drop in to chat with over 200 scientists, immerse yourself in interactive science demonstrations and peek behind the curtains at this top university's most exciting research facilities.

www.imperial.ac.uk/festival
 ☎ 0207 594 3375 | festival@imperial.ac.uk
 Imperial College London, Exhibition Road, South Kensington, SW7 2AZ



PINT OF SCIENCE

18TH-20TH MAY

Pint of Science festival brings top scientists to your local pub to discuss their latest research. This is your chance to meet the people responsible for the future of science. The format is simple - scientists hold down-to-earth talks over drinks and pub grub. The festival takes place in 11 cities across the UK with 400 of UK's best scientists, with a relaxed atmosphere, engaging questions and subjects ranging from galaxies to the tiniest viruses. Tickets and event details will be released in early April 2015 on the website.

www.pintofscience.com
 @pintofscience | contact@pintofscience.com



GLASGOW SCIENCE FESTIVAL

4TH-14TH JUNE

Glasgow Science Festival returns with its exciting mix of science and innovative events in venues across the city. Eat, drink and be merry with 'Tasty Science'; including chemistry-infused whisky tastings and scientist-curated dinner parties. Be enlightened by lasers and optics for the International Year of Light and learn the inspiring tale of James Clerk Maxwell, one of Scotland's most influential yet lesser-known scientists. From exhibitions and hands-on activities to comedy shows and films, there are umpteen ways to discover science right on your doorstep.

www.glasgowsciencefestival.org.uk
 ☎ 0141 330 5370 | sciencefestival@glasgow.ac.uk



THE ROYAL SOCIETY

SUMMER SCIENCE EXHIBITION 2015

ROYAL SOCIETY SUMMER SCIENCE EXHIBITION 30TH JUNE-5TH JULY

With over 20 fascinating interactive exhibits you can discover the science changing our world. Question the scientists themselves about the exciting research they are working on including smart materials, the immune system and fusion energy. This six-day event also features a host of free talks, debates and family activities.

www.royalsociety.org/summer-science
☎ 0207 451 2513 | events@royalsociety.org

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CARDIFF SCIENCE FESTIVAL 13TH-19TH JULY

Join us all as we celebrate Cardiff Science Festival in 2015 with over 30 events with something for everyone. There will be events during the week for adults and a family focus to the weekend. Come and explore the best science that Cardiff has to offer and discover new ideas.

www.cardiffsciencefestival.co.uk
focus@cardiffsciencefestival.co.uk

 Cardiff Science Festival
Gŵyl Gwyddoniaeth Caerdydd



ORKNEY INTERNATIONAL SCIENCE FESTIVAL 3RD-9TH SEPTEMBER

An island setting for journeys to the frontiers with speakers from Australia to the USA. Topics include dolphin communication, exploring the Solar System, the mathematics of the Neolithic, the chemistry of light, colours to dye for, Darwin's predecessors, Newton's ghosts, 100 years of general relativity, the amazing Ada Lovelace, new light on MS, ripples in the Dirac sea, Arab sci-fi, power from wave and tide – plus films, outings, exhibitions, food and drink, island visits, and music in a 12th-century cathedral.

www.oisf.org
☎ 01343 540844 | orkneyscience@gmail.com



HERSTMONCEUX ASTRONOMY FESTIVAL 4TH-6TH SEPTEMBER

Following on from the special 10th Anniversary last year, the Herstmonceux Astronomy Festival will be offering yet another full programme in 2015. With lectures, trade stalls, planetarium shows, telescope tours and family fun activities, there is plenty to fill in the three days. In addition to all these exciting activities, there will also be raffles, a beer tent and the chance to camp under the stars. Come and soak up the amazing atmosphere among the domes and telescopes of a world famous astronomical observatory.

www.the-observatory.org/astronomy-festivals
☎ 01323 832731 | info@the-observatory.org

SCIENCE CENTRES

Also check out these Science Centres to explore in the new Year...



THE DARWIN CENTRE, WALES

The Darwin Centre has its 21st birthday this year, celebrating over two decades of workshops, field trips, festivals, research, and fun. 2015 also marks the 10th year of the core educational programme the Dragon LNG Darwin Experience. The programme sees thousands of young people take part in STEM related activities every year, raising confidence, understanding, and access to the world of science, technology, engineering, and mathematics. The Darwin Experience is a partnership between the Darwin Centre, their core sponsors Dragon LNG, Pembrokeshire County Council and Pembrokeshire College.

www.darwincentre.com

☎ 01437 753193 or 01437 753196

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GREAT NORTH MUSEUM: HANCOCK, NEWCASTLE

Prepare yourself for an exciting journey through 350 million years of evolution and discover the story of our planet and its people; highlights include a planetarium, life-size T.rex dinosaur skeleton, mummies from ancient Egypt, a large-scale interactive model of Hadrian's Wall and major displays showing the wonder and diversity of the animal and plant kingdoms.

Open: Mon-Fri 10am-5pm Sat 10am-4pm, Sun 11am-4pm

Free entry.

www.greatnorthmuseum.org.uk

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Shazia Fardous,
Freelance Proofreader
and Copyeditor

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Prostate Cancer Research Centre WELSH 3 PEAKS CHALLENGE


Sunday 14th June 2015

It's back! The PCRC Welsh 3 Peaks Challenge gives you the opportunity to tackle the 3 most iconic mountains in Wales. On Saturday 13th June you will take on Pen Y Fan in the Brecon Beacons followed by Cadair Idris in Mid-Wales before moving on to Llanberis to tackle Snowdon on Sunday 14th June. The challenge is for teams and individuals.


Over 500 people will take part in PCRC Welsh 3 Peaks Challenge and the Snowdon500 Challenge over the weekend and we would love you to be one of them. Registration is just £45.00 and we ask you to raise £250 each.



To register or find out more go to www.snowdon500.co.uk or call Paul on 07446 534436 for an information pack.

If you would like more information about prostate cancer visit the Prostate Cancer Research Centre's website:
www.prostate-cancer-research.org.uk
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MINDGAMES

Test your knowledge with our Big Quiz set by **James Lloyd**

1 Which scientist recently decided to auction off their Nobel Prize?

- a) James Watson
- b) Peter Higgs
- c) Steven Weinberg

2 Daredevil François Gissy recently set a new world record with his rocket-powered bicycle. What was his top speed?

- a) 333km/h (207mph)
- b) 366km/h (227mph)
- c) 422km/h (262mph)

3 According to recent research, coffee tastes more bitter in what colour mug?

- a) Blue
- b) White
- c) Orange

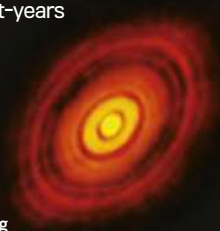
4 What odd sexual behaviour was recently filmed on Marion Island?

- a) A fur seal trying to have sex with a king penguin
- b) A leopard seal trying to have sex with a minke whale
- c) An elephant seal trying to have sex with an albatross

5 Captured by Chile's ALMA telescope, this is the clearest ever image of planets forming around a young star. Approximately how far away is the star, HL Tauri?

- a) 250 light-years
- b) 450 light-years
- c) 650 light-years

How far away is this emerging solar system?



6 This spectacular image is a newly reprocessed view of which of Jupiter's moons?

- a) Ganymede
- b) Io
- c) Europa



The red streaks are an iconic feature of...

7 According to Dutch researchers, how many bacteria are transferred during a 10-second kiss?

- a) 20 million
- b) 50 million
- c) 80 million

8 In November, the UK's first poo-powered bus went into service between which two cities?

- a) London and Brighton
- b) Bristol and Bath
- c) Liverpool and Manchester

9 When Italian astronaut Samantha Cristoforetti travelled to the ISS in November, what luxury item did she bring aboard?

- a) A make-your-own pizza kit
- b) A bottle of amaretto
- c) A zero-gravity coffee machine

10 Which of these technological terms was the Oxford Dictionaries Word of the Year 2014?

- a) Contactless
- b) Vape
- c) Bitcoin

11 Scientists in Israel found that children can start expressing pleasure at another's misfortune at what age?

- a) Two
- b) Six
- c) Ten

12 Complete the recent headline: "The British are born to be _____, new research finds"

- a) Brave
- b) Miserable
- c) Boring

13 Another headline to complete: "British novelist sends _____ into the stratosphere"

- a) Boiled egg
- b) Roast chicken
- c) Lamb chop

14 According to an online experiment, what is the UK's catchiest song?

- a) 'I Don't Want to Miss a Thing' by Aerosmith
- b) 'Wannabe' by the Spice Girls
- c) 'Don't You Want Me' by The Human League

15 This photo, which came third in the 2014 Nikon Small World prize, shows the eyes of what kind of spider?

- a) Black widow spider
- b) Tarantula
- c) Jumping spider



Which spider has these shiny peepers?

More puzzles online



Try solving puzzles from the BBC quiz *Only Connect* hosted by Victoria Coren online at <http://bbc.in/1vCOzuY>

QUIZ ANSWERS

HOW DID YOU SCORE?

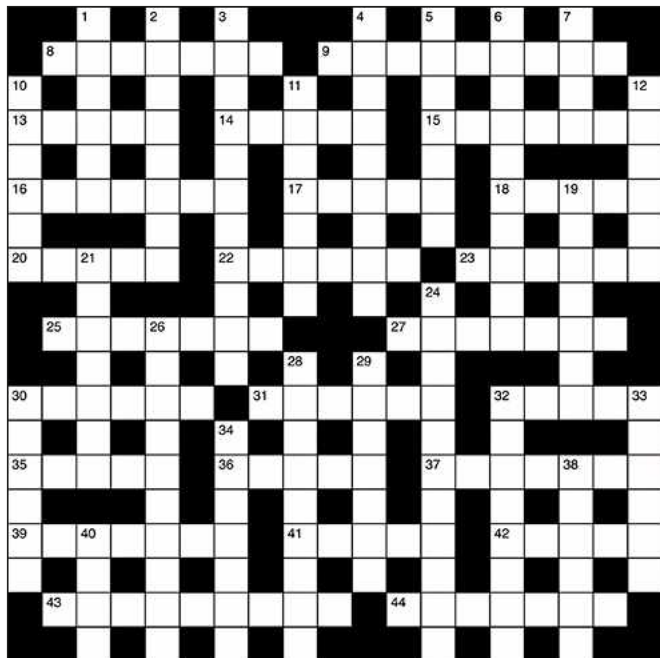
0-5 TWO LEGS BAD

6-10 FOUR LEGS GOOD

11-15 EIGHT LEGS EVEN BETTER

1a, 2a, 3b, 4a, 5b, 6c, 7c, 8b, 9c, 10b, 11a, 12b, 13c, 14b, 15c

FOCUS CROSSWORD No 173



ACROSS

- 8 Plague gets cub in trouble with hygiene problem (7)
 9 Paste contains strange marine element (9)
 13 Children's edition (5)
 14 Mouth made daughter terribly late (5)
 15 Pair has time for some poetry (7)
 16 Lie and cuss about how hot it is (7)
 17 Money for a large animal (5)
 18 Discover a tiny amount (5)
 20 Transaction includes British fur (5)
 22 Agreement that at least three notes were heard (6)
 23 Some fruit caught one form of rust (6)
 25 Involved brute in machine (7)
 27 Animal encounters barrier around bay (7)
 30 Motorist controlling software (6)
 31 Man forced to charge for a membrane (6)
 32 Bone incorporated by you and me (5)
 35 Discovery includes European monster (5)
 36 Imagine putting additive into drink (5)
 37 A Pole wandered around church, having a lot of time (7)
 39 Some heat generates a recoil (7)
 41 Cancel making a ring without last two (5)
 42 Tidiness between class and family (5)
 43 Ordain odd new church regulation (9)
 44 Nowadays set trap with old useful device (7)

DOWN

- 1 Last excursion finds us inside with a cough (6)
 2 Sticking together, chose to run - I have to follow (8)
 3 Holy site suffering inland fires (11)
 4 A derelict form of measure (9)
 5 Greek character finds only a tiny bit (7)
 6 Manufacturing river experiment (10)
 7 Flier meets German university students (4)
 10 Fish leave a sign (6)
 11 Artist's broken leg about to get firm (2,5)
 12 Underline anxiety (6)
 19 A bore worked in charge of oxygen (7)
 21 Turn exit round after graduate finds ore (7)
 24 Made a picture of aristocrat and butterfly (7,4)
 26 Tree providing money and food (10)
 28 One politician to point to routine opposition (9)
 29 Did moan about form of carbon (7)
 30 Change sides by mistake (6)
 32 Room is varying acidity, but it's the same shape (8)
 33 Clears away part of vision (6)
 34 Learn about following notes about a gland (7)
 38 No hard new particle (6)
 40 Fun bird (4)

SOLUTION TO CROSSWORD No 170

John Rawcliffe, Stuart Milner, Charles Caldwell, Alan Warker and Susan Wilton each solved issue 274's puzzle and receive a copy of *Mythbusters Season 8* (Discovery, £17.75).



WIN! A HISTORY OF AIR TRAVEL

The first five correct solutions drawn will each win a copy of *A History Of Air Travel: From Zeppelin to Concorde* (Go Entertain, £14.99). Entries must be received by 5pm on 5 February 2015. See below for more details.



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Post entries to *BBC Focus Magazine*, February 2015 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to february2015@focuscomps.co.uk by 5pm on 5 February 2015. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

TERMS & CONDITIONS

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Read more about the Immediate Privacy Policy at www.immediatemediaco.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown above. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.

HOLLYWOOD SCIENCE

Separating science fact from movie fiction

Tornadoes in Into The Storm

TORNADOES ARE ONE of the most destructive forces of nature. In their wake, they can leave a trail of devastation that's worse than the aftermath of toddler's birthday party. This month sees the DVD release of tornado-tastic disaster flick *Into The Storm*, in which multiple columns of wind batter buildings, suck people into the sky, and flip vehicles like burgers. But how likely are you to be totalled by a twister?

Unsurprisingly, it depends where you live. America, where the film is set, experiences around 1,000 tornadoes per year, of which five to 10 measure top whack on the tornado intensity or 'Fujita' scale. With their columns of air rotating at speeds of up to 515km/h (320mph), these can raze buildings and turn towns to rubble. Vehicles are damaged, not by being tossed into the air, but from tumbling across the ground and being pummelled by debris. And once in a while, as in the film, a single weather system spawns multiple twisters to create something truly terrifying. On 25-28 April 2011, 324 people lost their lives when an outbreak of 355 tornadoes swept across the US. In the

"In 2011, an Alabama schoolboy was whipped 9m (30ft) into the sky by a tornado"

same year, an Alabama schoolboy was whipped 9m (30ft) into the sky by a tornado that ripped the roof from his house. He survived with cuts and bruises – and quite a story to share at playtime.

In the US, tornadoes tend to form when warm, moist air moves up into an already spinning parent storm or 'supercell', and a column of less buoyant air sinks down. "The tornado forms near the intersection of the up and downdrafts," says meteorologist David Schultz from the University of Manchester. Doppler radar can be used to detect the rotating air in the supercell some 10-20 minutes before the tornado forms, giving national weather services a chance to issue warnings. The tornado then tends to move in a predictable direction (normally SW-NE in the US) at speeds of around 80km/h (50mph); they rarely do the rapid U-turns seen in movies.

"You can outrun one on a straight road, no problem," says Schultz. If you're still driving that M-reg Cavalier, though, we'd suggest not trying.

I, however, can feel smug. In the UK, there are just a few dozen tornadoes per year, and like our burgers and our belts, they tend to be smaller than their US counterparts. A key difference, says Schultz, is that British tornadoes generally come from linear storms – cold fronts that move down the country – rather than from supercells. No one is quite sure how this happens, but it's good to know that the only twister I'm likely to encounter is the one played at Christmas with sherry-fuelled relatives. ■



HELEN PILCHER is a science writer and comedian. You can follow her on Twitter: @Helenpilcher1

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